HENLEY'S ENCYCLOPÆDIA

OF

PRACTICAL ENGINEERING

AND ALLIED TRADES

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A PRACTICAL AND INDISPENSABLE WORK OF REFERENCE
FOR THE MECHANICAL ENGINEER, DESIGNER, DRAFTSMAN,
SHOP SUPERINTENDENT, FOREMAN AND MACHINIST.

Encyclopædic in scope, thorough and practical in its treatment of technical subjects, simple and clear in its descriptive matter, and without unnecessary technicalities or formulæ. The Articles are as brief as may be and yet give a reasonably clear and explicit statement of the subject, and are written by men who have had ample practical experience in the matters of which they write.

EDITED BY

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AUTHOR OF "PRACTICAL METAL TURNING," "MODERN MILLING MACHINES," "PATTERN MAKING,"
"TOOLS FOR MACHINISTS, AND WOODWORKERS,"
ETC., ETC.

ASSISTED BY A CORPS OF PRACTICAL MEN, EACH A SPECIALIST
IN THE SUBJECT OF WHICH HE WRITES.

PROFUSELY ILLUSTRATED.

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The Encyclopædia

OF

Practical Engineering and Allied Trades.

Files.—These owe their cutting properties to the action of a multitude of teeth, of scrape form, set diagonally so as to give a shearing cut. The tooth shapes are as shown in Fig. 1, A, which represents the shape left by the cutting chisel. In the best sand-blasted files the teeth

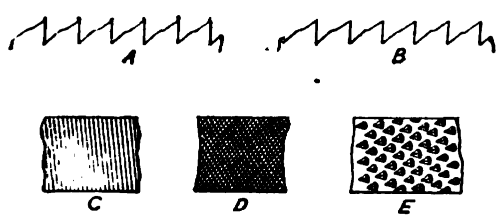


Fig. 1.—File Teeth.

assume the form in B, the stream of sand directed on the backs sharpening them up to a keen edge, which is stronger than the ordinary cut shape. There are two styles of cutting, the single, or float, C, and the double, D. The single is used chiefly by lathe-workers, wood-workers, and in sawmills, the double in all classes of metal-working. Rasps have their teeth formed by a punch, which leaves a series of single teeth upstanding, as at E. Each of these styles is made in six different cuts, the single in *Rough*, *Middle*, *Bastard*, *Second Cut*, *Smooth*, *Dead Smooth*, the double similarly; and the rasps in *Horse*, *Rough*, *Middle*, *Bastard*, *Second Cut*, *Smooth*. These differences relate to the size of the teeth and their pitching.

In Fig. 2, we have the next great difference in files, that of their cross sections, which occur in a number of sizes for each shape. The rectangular cross sections are shown first, the *square*, A, the *pillar*, B, which is a thick pattern of flat file; the *flat*, C, a thinner proportioned style; and when of small dimensions a *pottance* file; the *mill*, D, thinner than the flat; the *warding*, E, thinner still (in proportion to width). The *swaged reaper files*, F and G, differ in the form of their edges. Two styles used for saw-mill work are the *mill*, H, and the *topping*, J. A file having tapered faces is the *reaper*, K. Triangular shapes are the *three-square*, L, the *cant* file, M, and the *knife*, N. A combination of two triangles is the *feather-edge*, or *slitting*, O. Files derived from the circle are the *round*, P, the *pitsaw*, or *frame saw*, Q, the *half-round*, R, the *cabinet*, S, the *crossing*, T, and the *tumbler*, U. Two or three modifications based on these shapes are sometimes made. A *safe-edge* file is one in which one or more edges are left smooth,

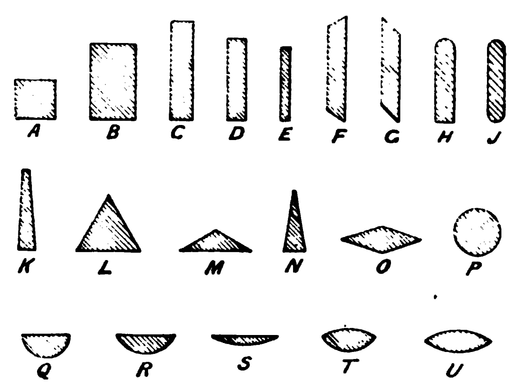


Fig. 2.—Sections of Files.

to be used close up to a shoulder without filing away the latter.

The longitudinal forms of files vary in being

parallel, or tapering to various degrees. In Fig. 3, A is a *parallel* or *blunt* file, of equal cross section throughout. A *dead parallel* file is one that is machined truly before being cut. An *equalling* file has a very slight amount of belly or curvature lengthwise. A *tapered* file, B, is either made with straight sides, or *bellied* as shown. The square file is tapered, C, while the three-square or triangular is both parallel, D, and tapered, E, as is also the *rat-tail*, F, and round, G. The semi-curved patterns are tapered, H, or parallel, J. *Knife reapers* have a handle forged on, K. *Rifflers*, L, have a handle formed in the middle portion, and curved file parts at the ends. *Rasps* are made in the same shapes, excepting that one, the horse, is parallel down its length, and minus any tang or handle.

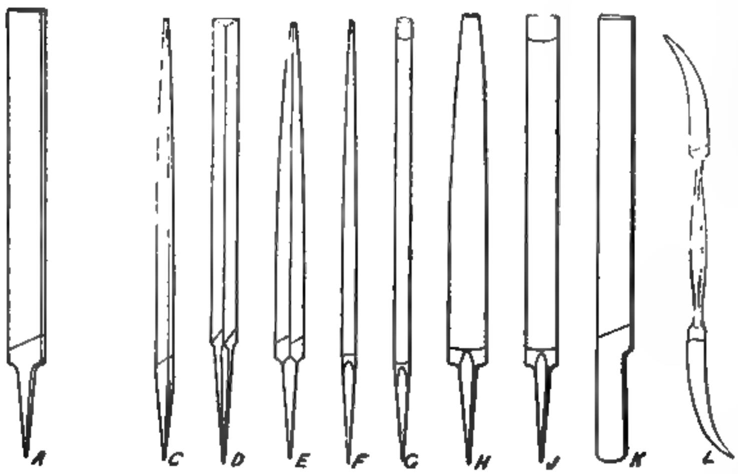


Fig. 3.—Longitudinal Shapes of Files.

For the majority of work the ordinary file handle is suitable, but when the hand must be raised up to clear the surface being operated on, some device has to be adopted, either that of cranking the tang, or fitting a special handle over it to embrace the tang, and press on the top face of the file.

Filing.—The chief difficulty in filing is that of endeavouring to counteract the tendency of the hands to move in arcs from the shoulder joints, which prevents the file from taking a straight course. Narrow surfaces are more troublesome to finish flat than broad ones; a file is controlled more easily when a hand is placed at each end than when both are gripping the handle (as must be done in filing blank-ended slots, &c.). In filing such work as keys, truth is more easily secured by making sweeping side or rather diagonal strokes, which make a flatter face and also remove material more effectively. The direction of stroke may be changed frequently, so that the lines cross, and the ridges are topped off with less effort. For slogging work a large coarse file should be used, working it right from shank to tip.

Pressure should only be given on the forward stroke, that on the back being released, otherwise the points of the teeth will be snapped off. New files should never be used on rough castings or forgings, but the skin should either be removed first with an older file, or the work should be pickled in acid. Brass or gun-metal should be the first metal on which a new file is used, followed by cast iron, and then wrought iron and steel; a file which still works satisfactorily on wrought iron will not cut brass rapidly enough. Oil or chalk are used on files to make them finish rather more smoothly, and to diminish "pinning," or clogging of the teeth with particles of metal, which are especially troublesome in fibrous metals. When these get in, they may either be brushed out with card-wire, or if stuck tight, picked out with a piece of pointed wire.

"Draw-filing" is a method of finishing accurately, by grasping the file ends and moving the tool up and down, with its body lying at right angles to the axis of the work, the resulting surface being perfectly flat, and the marks running straight longitudinally. For keys, force-fit shafts, and other such work, this is a suitable method to pursue. In filing hollow curves, care must be taken not to simply push the tool forward, or grooves and ridges will

be produced; a sweeping side motion should be imparted, to cause the lines to constantly cross and recross, topping off the ridges incessantly.

Filing Block.—A block of wood or metal used in the vice, and having either a shoulder to abut small thin pieces of work against, or vee grooves for circular work, while being filed; both of these classes being difficult to hold satisfactorily in the vice jaws.

Filing Machine.—A machine having a vertical ram working in jig-saw fashion, and holding a file passing up through a table, on which work is clamped. The back of the file works against a roller which keeps it up to its work. The machine is particularly suitable for filing dies (for metal stamping), gauges, templets, &c., having narrow edges, and difficult internal parts, which would be troublesome to file truly by hand.

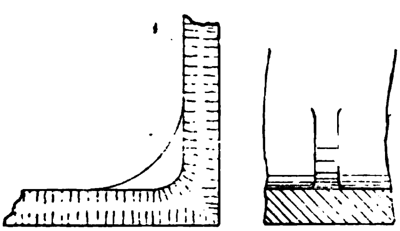


Fig. 4.—Fillets.

Fillets, Angles, or Hollows.—These, as they are variously termed, are put into castings for the very important purpose of avoiding the presence of sharp corners, and abrupt changes of form which involve risk of incipient fracture. Fig. 4 shows the effect of crystallisation in an angular casting, and illustrates the advantage of a hollow or radius. These are put into the patterns themselves in the best work, but in that of a rough and temporary character the moulder cuts them in the sand with the trowel, and sleeks and finishes them with a hollow smoother. There is no difficulty in cutting angles in the mould. But those made in this manner necessarily lack the uniformity of pattern hollows, and in the case of repetitive work the method becomes an expensive one. Still in elaborate patterns the additional cost of hollows is a serious item, and the following notes thereon may be of service:—

Straight hollows are planed from rectangular strips of wood. These are nailed along the straight portions of patterns, leaving sometimes, for the sake of economy, those round the curved portions to be cut by the moulder. When, however, these last are put into the pattern, they may, if the curve is very flat, be formed by bending the straight hollows around. But generally they have to be cut from the solid, or be worked out, and nailed on separately. To lessen the labour of cutting their curved outlines with gouges, leather, and lead fillets have been introduced. These, when pressed into the angles, and glued with a special composition, form true curves. Much time is saved when these are used around curves.

When fillets are turned in shallow bosses the direction of the grain ensures a keen edge, but in long bosses where the grain runs at right angles with the diameter, the short grain in the hollow would be weak. This is avoided by turning the fillet on a thin piece the other way of the grain, and bradding it on. When hollows are attached to pieces loosely dowelled, their lower free edges should be left thick, say nearly $\frac{1}{16}$th in., otherwise they soon become broken. Being left thick they are not so readily damaged, and the moulder can sleek the edges down. Where hollows are fastened by both faces they are brought to a feather edge. Angles of 45° do not look so neat as the hollows, and certainly cannot be so strong, but they are vastly better than sharp corners.

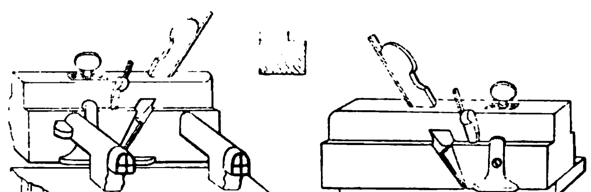


Fig. 5.—Fillisters.

Fillister.—A plane, Fig. 5, used by joiners for planing a rebate on the edge of a piece of wood. The advantage of the fillister over an ordinary

rebate plane is that, being provided with adjustable guides, it saves the trouble of gauging lines and planing carefully to them. Sometimes it is desirable to plane the rebate on the same side as that which the guide works against, and sometimes on the opposite side, according to which side the definite width has to be taken from. This necessitates two varieties of fillister. The sash fillister to the left of Fig. 5 is intended to cut on the farther side, and the moving or side fillister seen to the right, on the near side. A simpler form, known as a standing fillister, is not adjustable. Others of later introduction are made in iron, in the form of combination planes capable also of performing other operations. Fillisters are provided with slitting irons in advance of the actual rebate cutter, so that a clean cut at the side of the rebate is ensured. An example of the rebate cut by fillisters is seen in the upper part of the figure.

Filter.—*See* **Feed Water Filter, Oil Filter, Pressure Filter.**

Fin.—A thin lamina of metal around the edges of castings and forgings. Fin in castings forms when the moulds are not jointed closely, or when the boxes strain and lift due to liquid pressure. In forgings they are the surplus metal squeezed out by the action of the dies. Fins are fettled off in castings, and stripped, or compressed in forgings. *See* **Forging Dies.** In rolled bars fins result from a reduction of the metal, and they must be suppressed by turning the bars about in the rolls. If they are allowed to form, they chill rapidly and stress the rolls and are liable to break them.

Fine.—A prefix which is of a relative character. Fine dimensions, fine feed, or fine pitch, or fine grain. Fine hard, and fine grit relate to the texture of grinding wheels. Fine metal denotes a stage in copper smelting.

Finery.—*See* **Wrought Iron.**

Finishing.—A prefix which denotes the rolls employed in giving the final shapes to bar iron, and iron and steel sections. They are usually chilled to impart a surface gloss. Finishing cuts are the final fine cuts in machining iron and steel. Finishing tools may be the ordinary roughing tools set finely, or the broad tools with straight edges which impart smoothness and accuracy by a very fine cut.

Finning.—Pressing down the joint faces of dry sand moulds to prevent their fracture when dry. *See* **Dry Sand Moulding.**

Fire-Bars, or Furnace Bars.—The grate-bars of a boiler furnace. It is rather surprising how these simple fittings have been varied in design, and without permanently ousting the old plain type.

The object of fire-bars is to support the fuel, while allowing enough air for combustion to pass between them, and to permit the ashes to fall through. Naturally bars burn out rapidly, and before that occurs they often curve and twist badly. These facts explain points in the design.

Fire-bars are generally cast separately, Fig. 6, A, and laid loosely on their bearers, so that burnt

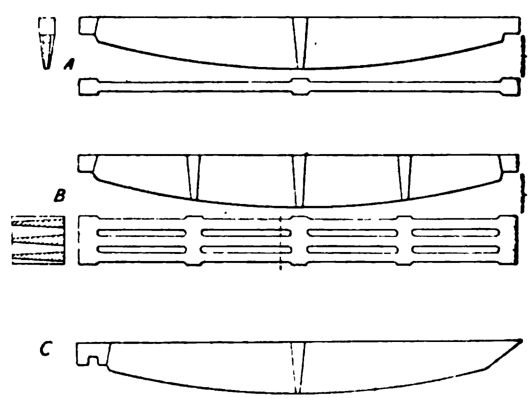


Fig. 6.—Fire-Bars.

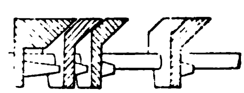
and twisted bars can be readily replaced. Sometimes they are cast in sets of three or more, B, being simply a repetition of the single bars. Some patented bars with air spaces may be regarded as a variant on this design. Long bars are bellied longitudinally on the bottom edge to stiffen them, and to enable them to resist the tendency to bend when red hot. They are tapered in cross section to enlarge the spaces for the ashes to fall clear through. Nibs are cast to make flank contact, otherwise the tapered form would not remain upright. The taper is not carried to the top edge by within $\frac{3}{4}$ in. or 1 in., because if it were, the burning down of the bars would widen the air spaces, which should not exceed from $\frac{3}{8}$ in. to $\frac{5}{8}$ in. Long bars are not so convenient to handle as

shorter ones, hence in long fire-grates, the bars are cast in two or in three lengths, so that lengths of 2 ft. 6 in. or 3 ft. shall not be exceeded.

Bars elongate in time with heat, hence they must be slack-fitted when new. Often one end is tapered to rest on a tapered bearer, Fig. 6, C, so that the bar can slide thereon during expansion by heat.

Wrought-iron bars do not stand so well as cast, and they need only be used where there is some risk of fracture occurring. The quality of cast iron for bars should be hard, nearly white, which may be obtained by remelting inferior scrap. Grey iron burns away too quickly.

Fig. 7 shows a patent form of fire-bar by Messrs Whitehead Bros., the principal feature of which is the angular shape in place of the ordinary vertical. Some of these have been in use for five and a half years without showing sensible wear. The chief advantage gained is that the air (or steam) cannot impinge on the crown of the furnace, being deflected by the angle, so that the fuel is consumed in a very complete manner, with avoidance of smoke. The bars are strung together on rods. They will work in connection with mechanical stokers.



Fire-box.—Denotes specifically a furnace of rectangular or box shape as used in the locomotive type of boiler; since a cylindrical furnace is not termed a fire-box, though its function is identical.

A locomotive fire-box is rectangular in plan, and nearly so in longitudinal and cross sections, but the sides are tapered upwards to allow of the free movement of the globules of steam. Such a design involves the free employment of stays, since the conditions of steam generation limit the thickness of furnace plates. The problem then becomes that of the transmission of the stresses to the stays, and leaving the areas unsupported by stays very small. The strength of each screwed stay is calculated to sustain the stress over the area immediately encircling it, and it is in tension. The girder stays, when such are used on the crown, are subject to bending action.

The next most striking feature of a fire-box is its large size, and its value as heating surface. In an average locomotive this is equal to about 1,500 square feet, or about 5 cubic feet per square foot of grate area. From one-third to over one-half the total heat produced by combustion is absorbed by the fire-box, notwithstanding that its heating surface is only about one-tenth or one-twelfth that of the tubes. Hence in endeavours to increase steaming capacity, attention is given to increasing the fire-box surface and efficiency rather than that of the tubes.

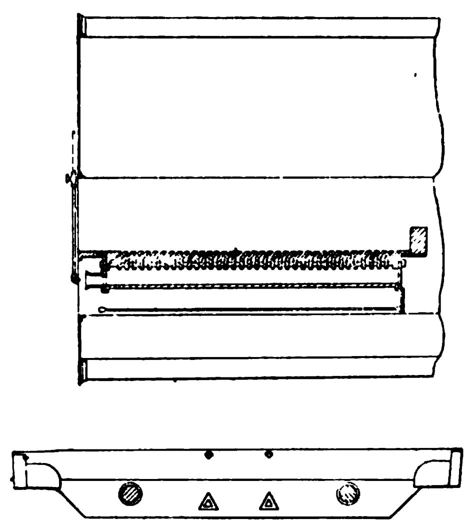


Fig. 7.—Whitehead Bars.

The fire-box is often termed the *inner fire-box* to distinguish it from the casing, or outer fire-box. It comprises the tube plate, the back plate, which has the fire hole, and the wrapper or covering plate. These are united to the throat plate, to the back plate of the casing, and to the wrapper plate of the casing.

The means of union are the foundation ring below, the screwed stays, the girder or sling stays, when used, the fire-hole ring, and the expanded ends of the fire-tubes.

Angle irons, formerly used, have given place to flanging, and hand flanging to that of the hydraulic press. The flanges of the tube and fire-hole plates face each other, and the wrapper plate is riveted to them.

The fire-box casing and the fire-box are riveted up separately, then the first named is riveted

to the barrel, and afterwards the fire-box is inserted complete with its girder stays. The foundation and fire-hole rings are inserted at the same time, and held with bolts while the rivet holes are drilled, and all riveted up.

The material used in fire-boxes is generally copper in this country, and steel in the United States. Steel has the advantage of higher ductility and of greater hardness to withstand the cutting action of the draught and fuel. The great disadvantage is its liability to crack.

Copper is better able to resist the effect of extremes of temperature than steel, and it is always worth its cost as metal. It is better if not absolutely pure, a trace of arsenic imparting a hardness to its surface. It is specified generally to have a tensile strength of 14 tons per square inch, and an elongation of 40 to 45 per cent. in 4 inches. It is required to bend double cold without sign of fracture.

Copper is used for stays in almost all cases, being better able than iron or steel to withstand the bending strains due to expansion and contraction of the fire-boxes. The central portions are turned down to give greater elasticity, and to avoid keen angles.

Fire-Bricks.—Furnace bricks made from fire-clays of a highly refractory character. They are prepared like ordinary bricks, by moulding, followed by air drying, and by exposure to heat for several days in kilns, in which they are allowed to cool down after the withdrawal of the fires. They shrink considerably during drying, by as much as from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. in length, the amount depending on the mixture of the clays. There is no fire-brick suitable for all classes of furnaces, but alkalies in any case must be low, as their presence increases fusibility. Silica bricks, though suitable for the roofs of reverberatory furnaces, would be useless for the bottom of a furnace, where they come into contact with metallic oxides. Also, though a fire-clay may be highly refractory, yet the wide and sudden variations in temperature present in furnaces would crack bricks made from that alone. To prevent this, the raw clay is first exposed to the action of the atmosphere, and then other substances are added as binding materials, such as burnt fire-clay, old bricks, powdered graphite, crushed coke, quartz, silicious sand, &c. The bricks are moulded in shapes to suit the class of furnaces, or the position occupied in the furnaces.

Fire-Bridge.—The bridge at the back of the furnace tubes in Lancashire and Cornish boilers. Its function is partly to prevent the fuel from being pushed off the farther ends of the grate-bars, partly to promote the mixture of the hot gases and air by retarding their escape into the flues.

Curious results have happened in regard to the height of fire-bridges. A high bridge impedes draught, and causes risk of overheating the top of the flue immediately above. Tentative alterations of 2 in. or 3 in. in height have sometimes made great differences in the efficiency of combustion. General rules are:—The air passage may be one-sixth the area of the fire-grate. Or, allow about 12 square inches of area above the bridge for each square foot of grate surface. In a 2 ft. 9 in. flue the top of the bridge is from 9 in. to 12 in. below the top of the flue. The length of one brick is the usual width of the bridge,—not more.

Fire-Clay.—Fire-clays occur chiefly in the coal measures of the Carboniferous strata, but they include many different varieties differing in degree of fusibility, due chiefly to the variations in the proportions of free, and of combined silicon. They are essentially hydrated aluminous silicates, with lime and magnesia in the form of carbonates; iron pyrites, free silicon, potash, and soda, with water. A good fire-clay should be as free as possible from calcic carbonate, iron pyrites, and ferrous oxide; each of which at high temperatures will combine with the free silica of the clay. The presence of alkalies impairs the refractory character of the clay. Stourbridge clay contains the following:—Si, 63·30; Al, 23·30; Ca, ·73; FeO, 1·80; Water, combined and hygroscopic, 10·30. South Wales clay contains Si, 67·12; Al, 21·18; Potash, 2·02; Lime, ·32; Mg, ·84; Fe_2O_3, 1·85; Water, combined and hygroscopic, 6·21, with a trace of organic matter.

Fire Engine.—The modern fire engine is an excellent example of the *multum in parvo* principle. It would be difficult to name a machine which comprises so much highly efficient mechanism in so small a compass. Necessity has

been the mother of invention. Little by little successive improvements have been effected. The annals of the great fire engine building firms are reckoned by the dates of these improvements, which are interesting records of those practical advances the sum of which goes to the making of the modern fire engine.

The capacity of such an engine may be gathered from the fact that the largest standard size made by Shand, Mason, & Co. is capable of pumping 1,000 gallons a minute, sending a 2-in. diameter jet to a height of 205 ft. and is of 95 I.H.P. Yet this mechanism is got into an over-all space of 14 ft. 6 in. long, by 6 ft. 6 in. wide, by 8 ft. 6 in. high. Such a result is only possible by virtue of the high efficiency of the design, the economy of space, the reduction of weight in materials, without sacrifice of strength, and a thousand and one details the beauty of which only the engineer is able to appreciate to the full. The machine, like the locomotive, is absolutely the product of evolution.

Fire engines range from small hand appliances to motor engines of large pumping capacities. The horse-drawn steam pumping engine has held its position for many years, but is being pressed by the motor propelled engines, which travel much faster, but cost more for maintenance. The manual fire engine is suitable for localities where fires are rare, or for private use in buildings, or on estates. The pumps in this class of machine are usually worked by levers. Their capacity at best is much less than that of the average steam fire engine, but they can deal effectively with small fires. A chemical mixture instead of water is often pumped on fires that have not gained much headway, thus avoiding the damage that large quantities of water generally cause. Nozzles of different diameters are used at the end of the hose, according to the rate at which the water is being pumped, and the distance it has to be thrown. Attachments are also provided for throwing the water in a spray, covering a large area close at hand if desirable.

The manual fire engine of Messrs Merryweather & Sons, Ltd., dates from 1851, and successive improvements have been made by which these engines have been rendered more powerful without increase in weight. The "Greenwich" type embodies the firm's best practice in this and numerous other details. In the No. 3 size, being that most frequently used, twenty-two men can pump 136 gallons per minute, 120 ft. high, an excellent performance for a manual engine. In one of larger size, thirty men will pump 150 gallons per minute, 130 ft. high.

The construction of the Merryweather manual engine (Fig. 8, Plate I.) includes the following parts:—The cistern, of copper, mounted on wheels of wrought iron. Longitudinal pockets of teak and mahogany attached to the cistern carry the suction hoses, strainer, branch pipes, and wrenches. The cistern contains two pumps which are actuated by pumping levers, on the long handles of which, of steel tube, the men work. The pumps, plungers, valves and valve-box are of gun-metal, and are provided with an air vessel of copper, so making perfect provision against rust. The valves can be examined and re-ground on their seats. The pumps will draw water either from their own cistern or through a suction pipe. They will draw water 25 ft. vertically through a suction pipe, or they may be fed by buckets at the hinder end of the cistern. Two or more engines should be used when the water supply is situated at a long distance from the fire, one being located close to the water, pumping into the one at the fire. The force with which water is thrown is as efficient as the quantity in extinguishing a fire.

Merryweather engines for 46, 38, and 30 men will pump through 1,000 ft. of delivery hose, those for 26 and 22 men through 750 ft., while the smaller engines will pump through lengths varying from 300 ft. to 600 ft. But this assumes a moderate distance only from the water level to the place of discharge.

The latest Merryweather steam fire engine is the "Greenwich Gem." It embodies a number of excellent features. The vertical boiler has water tubes, both inclined, and curved for elasticity. The firm holds strongly to the practice of rear stoking, in preference to that at the side. The advantages are that the engine driver can light up and attend to the fire while *en route*, that he is not hampered at all by narrow streets, and that the condition of the fire can be seen continuously.

To avoid difficulty in making hose connections, these for suction and delivery are extended on each side of the extreme rear of the frames, where they are connected up out of the way of the engine driver.

The engines and pumps, situated at the front of the boiler, are a compact piece of work. They are of the vertical double-cylinder type, the cylinders being uppermost. These are of cast iron, and lagged, the slide-valves being situated in a central steam chest. The pumps are of gun-metal, cast with the crankshaft bearings, and connected to the cylinders with turned steel stays. They are double-acting, driven direct from the steam pistons, the rods having slotted crossheads to drive the crankshaft from which the slide-valves are worked. A point to note in the pumps is the accessibility of the valves, which are exposed on the removal of a cover on the valve chest. The mere loosening of a nut removes a pair of valves, and a damaged valve can be replaced within from 3 to 4 minutes from the time of stopping to restarting the engines. The valves are of india-rubber, and the guards and gratings are secured with copper studs. A by-pass valve in the pump opens a communication between the suction and delivery passages, so that the engine may start against a head of water in the hose.

Messrs Merryweather have an oil-fired engine, the motor "Fire King" supplied to the London County Council and others. It will travel at speeds of from 25 to 30 miles an hour, can ascend gradients of 1 in 6, and its capacity is 500 gallons a minute, throwing a 1¼-in. jet to a height of 160 ft. The boiler is petroleum fired. Complexity of parts has been avoided by making the same cylinders and pistons furnish both the pumping and the motive power. As both operations are never required simultaneously this is very easily done through a countershaft which can be thrown in or out of gear. Steam can be raised to working pressure in from 6 to 8 minutes, from cold water, or in 60 seconds if a low pressure is kept up continuously by a gas burner or oil heater while the engine is in the station. The engine carries water and fuel for several hours' working, which includes either travelling on the road, or pumping when it has reached its destination. The wheels are fitted with solid rubber tyres and non-skid chains.

Fig. 9, Plate I., illustrates this type of engine, which is similar to those supplied to London. It has the addition of a chemical engine for first-aid, which is carried under the main box in front, and the reel for chemical hose is fitted above the box as illustrated.

The following very brief remarks have reference to the more salient points of the Shand, Mason fire engines:—Fig. 10, Plate I. As rapid steam raising is essential, the boiler claims first attention. This is a vertical type with inclined water-tubes, crossing the fire-box in each alternate row at right angles. The working pressure is 125 lb. to the square inch. The fire can be lighted and steam of 100 lb. pressure can be raised from cold water under ordinary circumstances in 8 to 10 minutes while travelling, without any stoking; but by the use of a new exhauster fan arrangement, the times mentioned are reduced to 5 and 6 minutes. Yorkshire iron is used in the boiler, with the longitudinal seams welded, and brass tubes.

The engines are of the double vertical type, adopted since 1889. They work directly on to double-acting vertical pumps, the two being rigidly connected. Two piston rods convey the movement of each piston to its pump rod. The crankshaft is driven by connecting rods of special type running from a joint in the head or cross piece of each pump rod. The eccentrics for working the slide-valves of the engines are situated at the ends of the crankshaft. The piston rods, and the rods for the slide-valves and pumps are of bronze, the pumps of gun-metal, and all surfaces with which the water comes in contact are of these alloys, or of copper, so that corrosion cannot occur when an engine has been idle for a considerable period. The moving parts are balanced to work steadily at high speeds.

By means of the oil-fuel apparatus, adopted since 1893, steam can be raised to 100 lb. in from 1 to 1½ minute, when 20 or 30 lb. of steam is maintained, as in the London Fire Stations. One great advantage is that there are no sparks or flying cinders escaping from the chimney, another is that no preparation of the furnace is necessary when the engine re-

turns to the station. Another improvement is the boiler heater—a miniature cross-tube boiler —by the use of which a low steam pressure may be automatically maintained while the engines are at the fire station. It may be regulated from boiling point merely, to 20 or 30 lb. pressure of steam. Variable steam expansion has been adopted since 1898, by varying the point of cut-off from three-fourths to one-half the stroke. The amount is read on an index plate at the back of the lever that operates the expansion gear. Besides the economy secured, fewer sparks escape from the chimney, due to the softness of the exhaust.

Side stoking is adopted in preference to stoking at the rear. The principal advantage claimed is that the engine driver and the firemen are not in one another's way at critical times when stoking, and the coupling up of hose has to be done with all speed. Another point in its favour is that the pumps can be arranged considerably lower, giving a decided advantage when pumping from a depth, the lowering of the centre of gravity also allowing the engine to travel better.

Fire engines may often be employed for other duties than extinguishing fires; as for transferring water from one site to another, or removing water from places where it is not wanted, for flushing sewers, and washing silt and mud from places where it has collected, for washing buildings, irrigating land, &c. Floating fire-pumps are also used on rivers for extinguishing fires.

Fire Flues.—Furnace Flues, as distinguished from smoke flues.

Fireproof Structures. — An absolutely fireproof structure may be regarded as impossible if material that would burn is stored within it, or inflammable buildings are close to it. No building can sustain without damage the application of intense heat unequally applied, and sudden cooling by cold water. Even without the latter the effect of expansion by heat is almost necessarily disastrous.

When iron began to take the place of wood for the framework of floors and roofs it was supposed that as the materials were not inflammable the buildings could not be injured by fire. But experience has shown that the expansion and bending of wrought members in a fire is more dangerous to the walls of a building than if such members were of wood. Cast iron seldom gets hot enough to bend, but it often cracks under the application of cold water in a fire. Stone cracks also when subjected to great heat.

The best fire-resisting materials are brick-work, including fire-brick, terra-cotta, &c., and concrete, and plaster. These are the materials that are used in all fire-resisting structures, but iron and steel are generally employed also, protected by the other materials, provision being made where possible for the greater expansion of the metal. Brick-work alone is used largely, and brick arches are preferred to joists or girders over openings in walls.

To prevent fires in one room or floor spreading to others it is also necessary to have means of closing all doorways, stairways, and windows, so that they shall be as impassable barriers to the fire as the walls and floors themselves. A building, therefore, with open stairways or lifts, wood doors, and no protection to windows is not fire-resisting.

Next to brick-work used alone, reinforced concrete is the best fire-resisting material for building. The metal embedded in the concrete is protected from the heat to a great extent, and the combination gives great strength with less bulk than would generally be required if brick-work alone was employed. In floors especially, brick arches would occupy too much depth. For exterior walls the appearance of concrete is not considered equal to bricks, nor is there quite so much advantage in employing it as in the case of floors. In floors, metal or wood joists are usually essential, and these can be more easily protected by concrete or plaster than by brick-work. There are innumerable methods of constructing such floors.

Special attention has naturally been paid to the construction of fireproof floors, because formerly when they were of wood they invariably became burnt out, while the brick walls remained standing, or suffered injury only through the breakdown of the floors. As brick-work for floors is generally impossible, a combination of metal and concrete is the alternative, and the methods of arranging this combination are numerous. Where girders

or columns have to be protected, the concrete or plaster is usually not applied directly to them, but to metal lathing, or expanded metal attached to the surface, with a space between.

Firing.—The art of firing consists in so regulating the relative supplies of air and fuel that the most perfect combustion possible under the crude practical conditions of the furnace shall take place. Good combustion cannot take place with heavy indiscriminate firing. At the moment of throwing fresh coal upon the fire, and for the few minutes immediately following, there is a rapid liberation of gases—carbon, hydrogen, and hydrocarbons. During these periods a large and immediate admission of air is necessary to burn them up, otherwise a considerable proportion of them will pass off unconsumed. With heavy firing and natural draught it is impossible to obtain the necessary quantity of air. Light firing with frequent charges is therefore economical. The fuel must be introduced in such quantities that no perceptible amount of coloured gases passes out of the chimney. The fuel must also be distributed judiciously over the incandescent mass beneath.

The proper way to fire in Lancashire and Cornish boilers furnished with a dead plate is to throw the fuel upon and a little way beyond the dead plate, and leave it there until coked. When coked it is thrust forward over the clear fire beyond, and fresh fuel thrown on the front of the fire. In locomotive boilers the fuel is flung into the four corners and allowed to coke, afterwards being drawn towards the central portions of the grate area. Firing thus, the gases come off slowly, and the oxygen in the air is allowed time to enter into combustion with them. With increase in draught the fire can be thicker, because a larger quantity of air passes through and over the grate in a given time. So that with forced draught it is necessary to keep a thicker fire and to fire more heavily in order to derive the fullest advantage from the increased quantity of air used. With a thin fire and forced draught the air tends to cool the fire, and there will not be sufficient fuel to combine with all the oxygen of the air.

In consequence of the very brief period available for the diffusion and intermingling of the atmospheric air with the gases on the hearth of a boiler furnace, only amounting to the fractional part of a second, various methods have been devised to promote and favour the chemical reactions necessary to perfect combustion. This is the essential secret of good hand firing. It is provided for in the various systems of machine stoking, and in forced draught. Many have been the devices resorted to in order to introduce the air in those localities where it will best promote combustion. Speaking generally, the aim is not to permit the inrush of a body of cold air in mass, but to introduce it at various areas, more or less broken up into layers or jets, so that its union with the gases may be effected immediately and completely instead of partially. In various systems the gases have been introduced below the fire-bars, passing up through them in jets above the grate from the front end and over the fire-bridge.

To ensure the perfect combustion of the chemical elements liberated from the fuel, it is desirable to liberate air both above and below the fire-bars; in what proportions depends upon the thickness and condition of the fire at a given time. Air in passing up through the grate-bars becomes charged while in contact with the fuel with carbon, forming carbonic oxide. Unless this meets with a supply of oxygen above the fuel, sufficient to convert it into carbonic acid, it will pass off, causing a loss of heat, and if the chimney temperature is high enough, will burst into a blue flame on meeting with oxygen at the mouth. This will occur with a thin, clear fire in the absence of a proper supply of oxygen above the grate-bars.

Again, in the case of a thick fire in which air is introduced only from below, the probability is that the entire combustion will be imperfect. The carbon and hydrogen distilled from the coal in the process of coking require an ample supply of oxygen to produce steam, and the oxides of carbon. If this supply is not forthcoming, or if present, and the furnace temperature is fallen too low, much of the carbon will pass off unconsumed as black smoke, and a portion of the coal-gas will escape in the form of hydrocarbon, only igniting at the chimney top on meeting with the air.

The experiments of Mr Spence showed that neither with a thick nor a thin fire is it possible,

Fig. 8.—Merryweather Manual Fire Engine

Fig. 9.—Merryweather Motor Fire Engine, combined with Chemical Engine

Fig. 10.—Shand-Mason Fire Engine, with Double Vertical Engines.

Fig. 16.—Flanging Press.
(Henry Berry & Co., Ltd.)

Fig 17.—Flanging Plant. (Henry Berry & Co., Ltd.)

To face page 12.

with forced draught introduced underneath the grate-bars only, to ensure perfect combustion. Increasing the air pressure from beneath does not meet the case, because it only increases the rate of combustion, and not the diffusion of the air. With thin fires the air blows through them strongly, producing cracks and holes through the fuel, so that the air passes up in dense streams or jets instead of being equally diffused or stratified.

Firing Chamber.—The lighting or ignition chamber of a gas engine.

Firmer Tools.—*See* **Chisel** and **Gouge.**

First Motion.—A term applied to the first shaft, wheel, or belt in a train which communicates motion to the rest.

Firwood.—A term often used in the same sense as *deal*, to denote the common varieties of softwood, spruce and pine, used in building.

Fish Bellied.—A common term used to denote a girder having the bottom edge or boom curved.

Fishing Tackle.—A tackle used for finding and lifting the valves from deep bore-hole pumps. A good device is that of a kind of grab in which pivoted dogs catch under a mushroom head on top of the valve spindle, and so lift it.

Fish Oils.—Sperm, seal, cod, &c. *See* **Oils.**

Fish Plate.—A butt joint made by a strip of plate, covering and uniting the abutting pieces. The joint is a *fish*, or *fished* joint.

Fitter.—A craftsman whose duties lie in the correction and final union of mechanisms. His work presupposes inaccuracy in the previous departments, which it is his place to correct by filing, scraping, or grinding. There can be no fitting in a perfect gauge system, but assembling only. The fitter therefore deals generally either with a larger type of work that could not be well handled by a perfect interchangeable system, or with a class of which there is not sufficient volume to pay for the installation of such a system. The fitter may, nevertheless, have to work to gauges in order to allow of interchangeability in the parts of high class motors or mechanisms, but that is not the same thing as producing the same results directly by machine methods. It is hand work against, say, turning, grinding, milling, &c. Much of the success of the work of the fitter lies in exact and careful measurements and tests. Fine handicraft is useless without these. A remarkable fact is the great increase of late years in the system of working by fixed gauges, caliper gauges, and micrometers; taking the place of the old shifting calipers, and rule. The work is thus precise to dimensions as well as mutually fitting, and is therefore in harmony with the interchangeable system in which most repetitive work is now being absorbed.

Fitting Shop.—The department in which the smaller mechanisms or parts of mechanism are brought together after they leave the turnery and machine shop. Its principal equipment is vice benches, and in some shops grinding wheels are distributed about. The work is chiefly filing, scraping, reamering. Obviously the size, equipment, or even the importance of the shop itself depends on the class of work done in a firm, and the system by which it is produced. Generally now it is a department that tends to lessen in importance. The fitting shop may be on a ground floor, especially if the work is rather heavy. But generally it may be on an upper floor, or a gallery flanking a main shop. *See* **Erecting Shop.**

Fixed Cranes.—A fixed crane may have a top and a bottom pivot, or it may have a bottom pivot only; but in either case the pivot seating is definitely fixed and the crane can only command the area contained within its radius of action.

The simplest form of fixed crane is the wall jib, generally used in connection with a hand or power winch. Similar cranes are used in warehouses, but the hoisting gear is generally built on the crane frame itself. Such cranes are also made with a bottom pivot only; they are then termed independent cranes. The same general outline and method of support is also common to forge and foundry cranes; but in these cranes a definite racking motion is arranged for, so as to give a means of varying the radius. *See* **Foundry Crane** and **Forge Crane.**

Another group of fixed cranes are those used in railway goods yards, &c., where overhead supports are not available. The foundations are of concrete, and the central post goes down to a seating from about 4 ft. to 7 ft. below the ground level; the post is fixed and the crane revolves

around it. A Fairbairn crane is a fixed crane. The ordinary Scotch derrick is usually a fixed crane. Fixed cranes are built up to the largest capacities for dock service, and are operated either by steam, hydraulic, or electric power.

Fixed Eccentric.—The ordinary eccentric sheave, for use with link work, for forward and backward gear. The term distinguishes the type from the earlier shifting eccentric with which all reversing engines were once fitted.

Flame.—When gases, or substances which yield combustible products, are heated to a certain temperature, flame is produced. Flames vary considerably in their heat, luminosity, shape, and colour. As stated under **Combustion**, heat and light in a flame are not necessarily related, luminosity being due either to the presence of incandescent particles of solid matter, or to the fact that the gas is of a high density. The hydrogen flame is non-luminous, but becomes luminous on subjecting it to a pressure of twenty atmospheres, or on introducing powdered charcoal into the flame. The colour of flame depends on the substance undergoing combustion; cyanogen burns with a pink flame, carbon monoxide with a blue flame.

Most flames are hollow, and if issuing from a jet may be divided into three distinct parts, easily observable in a candle flame:—(1) an innermost cone-shaped dark portion composed of unburnt gas, (2) a luminous envelope of incomplete combustion, (3) a non-luminous envelope of complete combustion. The gradation from the central unburnt gas to the exterior zone of complete combustion is due to the greater or less contact with the oxygen of the air. The Bunsen burner is simply a device for introducing an abundant supply of oxygen to the flame of coal-gas. The air drawn through the holes at the foot of the tube mixes with the gas and ensures complete combustion; there are no zones of unburnt or partially burnt gas, and the blue, non-luminous flame gives off great heat.

Flame Arc Lamp.—An arc lamp of the enclosed type, but in which the outer globe forms the enclosure; no inner globe is used. The carbons are in the form of long thin rods, which are placed in inclined tubes, their points being kept apart the distance of the length of arc, and feeding by gravity.

A magnetic field produced by a shunt winding, and also between the carbon points by reason of their angle to each other, has a blowpipe effect upon the arc, drawing it out into a large flame, and producing in effect a large luminous body of gas of great illuminating power.

The carbons prepared contain salts of sodium, which give the light a golden colour. The flame arc lamp is most suitable for the lighting of large areas; it has a large area of diffusion, and the light is evenly distributed. A lamp giving an illumination of 1,000 candle power requires only 5 ampères; this is therefore an economical form of arc lamp which is now coming largely into use.

A description of the "Bremer" lamp, one of the first makes of flame lamps, will be found in the concluding paragraph under **Arc Lamp**, and also the mechanism illustrated in Fig. 129 in that article.

Flame Plates.—The plates exposed to flame in a boiler furnace, being the upper plates of a furnace flue, or the crown of a fire-box.

Flanges.—Specifically broad extensions on the ends of pipes, valves, &c., which serve as means of union for bolts. Flanges are cast with cast pipes and bodies, but riveted on or screwed on in various ways in mild steel pipes, or brazed on in copper pipes. They meet by plain faces, or by checks and shoulders of different shapes, or in some cases they have swivel joints. They are cast in iron, steel, brass, or stamped in malleable iron and steel. They are united with common black bolts fitting in cast holes, or with turned bolts in drilled and reamered holes. Examples occur in these volumes. Flanges are turned in good work; only in a very rough class are their faces left untooled, and jointed with gasket, or millboard.

The present interest in flanges lies in the question of their standardisation. The subject is beset with difficulties. Out of 120 British and foreign firms whose lists were collected by Mr R. E. Atkinson in 1902, in no two cases did the tables and dimensions coincide in every particular. A standard list is adopted in the United States by the valve and fitting manufacturers, to apply to pressures of from 125 to 200 lb. In Germany there are two standards, one for steam pressures up to 118 lb., the other

for pressures from 118 to 294 lb. The (British) Engineering Standards Committee have recommended that flanges should be standardised in four classes :—

1. Low-Pressure Standard, for steam pressures up to 55 lb., and water pressures up to 200 lb. per sq. in.

2. Intermediate-Pressure Standard, for steam pressures over 55 lb., but not exceeding 125 lb. per sq. in.

3. High-Pressure Standard, for steam pressures over 125 lb., but not exceeding 225 lb. per sq. in.

4. Extra High-Pressure Standard, for steam pressures over 225 lb., but not exceeding 325 lb. per sq. in.

The numbers of bolts are multiples of four; as four, eight, twelve, sixteen; without which interchangeability is impossible, when attaching fittings at different angles.

Uniformity in the diameter of bolt circle, and in the number of bolt holes for a given size of flange, with uniform dimensions of flanges for varying conditions, entail compromises, and dimensions not strictly in harmony with stresses, but that is unavoidable in any attempts at standardisation.

The term flange has a wider significance, being applied to numerous objects in which ribs or members stand at right or other angles to another, irrespective of whether they are employed as a means of bolt attachment or not. Thus a common joist is a flanged beam. A flanged seam denotes a joint made by flanging tubes for the purpose of union, as in some furnace flues, and in the shells of some vertical boilers. A flanged wheel is a railway or trolley wheel having either one or two flanges; a flange rail is a flat-bottomed rail.

Flanging.—Turning over the edge of a plate or sheet, or the ends of a tube, in order to provide a means of union to another portion. Flanging in modern boiler practice takes the place of many angle joints formerly employed. It is safer, being less liable to groove, because more elastic. Fig. 11, A, shows a flanged crown of suitable proportions. Its elastic capacity and superiority to an angle are at once apparent. Flanging is done by hand hammering, or by hydraulic power pressure.

Bending blocks are employed in hand flanging to serve as guides by which to curve the edges. Round-faced wooden mallets are used in order not to bruise the metal, but final corrections are made with sledges. The work is held down with a clip cottered across, or by other convenient methods, similar to those illustrated under **Angle Iron Work**, while a portion of the edge is being turned over. Then the piece is removed to the hollow fire of bricks, covered with a plate, and another heat taken, and returned to the bending block, and re-cottered for bending the next section, and so on until the job is completed.

Cross tubes are flanged while held horizontally on a block supported on a stand. They are manipulated with a cross handle, against which the helper throws his weight in opposition to the blows of the smith. Fig. 11, B, C, shows how flanging of cross and furnace flues is effected when done by hand, B and C illustrating successive stages of the work. These are done by machine in large shops. Furnace flues were formerly flanged by hand, but now by machine. *See* **Boiler Flue Flanging Machine**. The same remark applies to steel mouthpieces, and all work of that class.

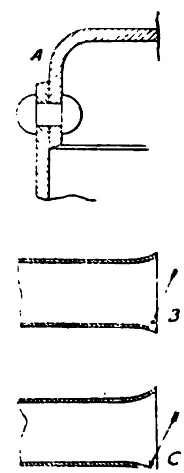


Fig. 11.—Flanging.

The flanging of tube plates, smoke box sheets, and throat plates was formerly done by hand, but now in dies. If done by hand, flanging blocks are necessary, and the edges are turned in successive heats and stages, occupying several hours for each plate. Flanging between dies is done at a single heat, and occupies less than two minutes in the actual pressing, exclusive of heating and corrections. But the apparatus used is costly, and separate dies are required for every size and type of boiler. *See* **Flanging Press**.

Hand flanging stresses and injures the metal, which is a consideration quite apart from the tedious nature of the process. There are certain temperatures suitable for doing work upon

iron and steel, and it is not safe to work these materials at other heats. With a high quality of iron there is less risk of injuring the fibre by successive heating and flanging than there is with steel.

The most injurious heat at which steel can be worked is that at which the red fades away and blackness begins to supervene. It will stand bending and hammering cold with far less injurious effects than it will while at the temperature say of melted lead, tin, or tallow. The ductility of steel is also impaired when work is done upon it at locally varying temperatures. When a plate or flue, therefore, has been flanged at successive heats by hand, subsequent annealing is necessary if evil effects are to be avoided. This is not essential when flanging is done by machine, the red heat remaining after the work is completed.

Flanging Press.—A hydraulic press which is designed for turning over flanges between

Fig. 12.—Hydraulic Flanging Press. (Fielding & Platt, Ltd.)

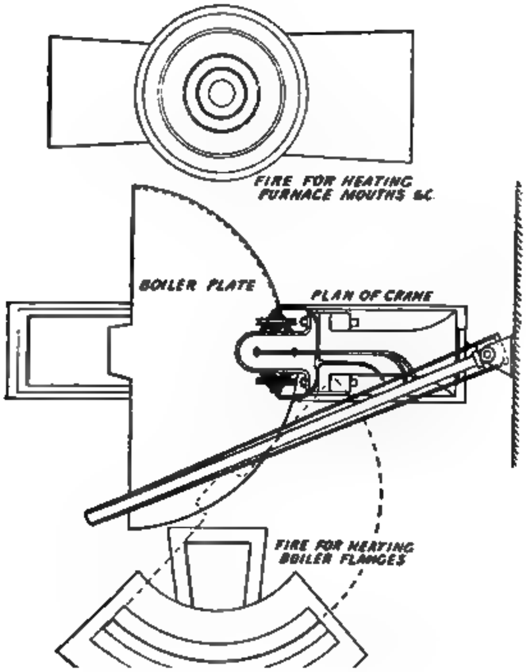
dies; in some cases complete at one heat, in others in successive heats. Though termed flanging presses from their main function, they are used for many other purposes; as, pressing frames of railway wagons, bending cranks, and other forgings, and for stamping, and punching; all of which can be done by the substitution of different dies.

The regular press, used largely for turning over the flanges of locomotive fire-box sheets, is shown in Fig. 12. The press cylinder is in the foundations, the ram A rising when pressing. This lifts the plate carrying stools, to which the power flanging die is attached. Between this and the upper die, which is attached by stools to the crosshead, the work is flanged. The height of the crosshead is adjustable to suit different dies and pieces of work. Precise adjustments of the work to be flanged are made through a plate (not shown) which is elevated by the four small press rams. The piece of work is thus held against the upper die, while the lower one is brought into action.

The dies required for large plates, as those of locomotive fire-boxes, are expensive items, but the expense is generally well covered by the large numbers of similar plates required. But for odd jobs such expense is not warranted. The plates for marine boilers are too large to be flanged at one heat. Some kinds of smaller work also cannot be flanged by a single squeeze. To cover all these cases the machine shown by Fig. 13 is made by Messrs Fielding & Platt, Ltd., to accomplish the flanging in detail (they term it a *progress or step-by-step system*). There are three rams, two vertical, and one horizontal. A length of several feet to be flanged, is heated, and laid on a segmental block, cast to suit the job, and held thereon by the outer vertical ram. The inner vertical ram then turns down the flange. The work is shifted until several feet are thus bent, and then the horizontal ram is brought into action, squaring up the flange neatly. The two vertical rams can also be coupled to operate with their united power on dome ends, furnace mouths, &c. Some of these utilities are shown in Figs. 14 and 15.

Fig. 16, Plate I., shows a large hydraulic flanging press, with one main, and two side rams, the arrangement of piping and the working valves being clearly seen. Ample tee-slot provision is made, on faces and sides, to attach various styles of dies. Fig. 17, Plate I., gives a view of the lay-out of a flanging plant, with press, crane, and furnace.

Flap Valve.—A leather valve stiffened with



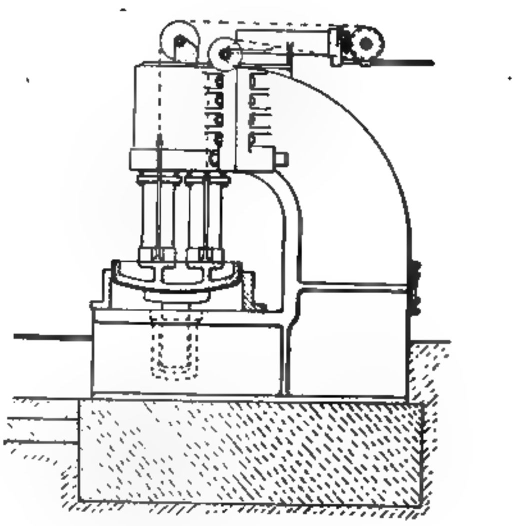


Fig. 14.—Flanging Dome Ends, with Lower Cylinder in use.

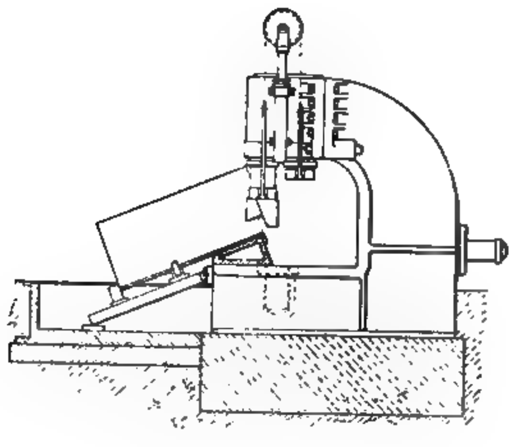


Fig. 13.—Hydraulic Flanging Machine, with Plan of Crane, and Furnace Arrangements.

Fig. 15.—Flanging Furnace Mouth.

plates of iron or brass, and hinged at one side; used in lift pumps, and lifting vertically.

A plain form of flap valve is also employed for sewage outfall works, an example being shown in Fig. 18 (Glenfield & Kennedy, Ltd.). The flap cover is hinged with short links, and falls by gravity. The shackle at the bottom forms an anchorage for a chain which goes up into a brick-lined chamber, and is pulled up or lowered by a barrel and worm gear. Some valves are closed with a balance weight. Two-way valves are hinged at the junction of two pipes, and the flap has double faces, to close the mouth of either pipe.

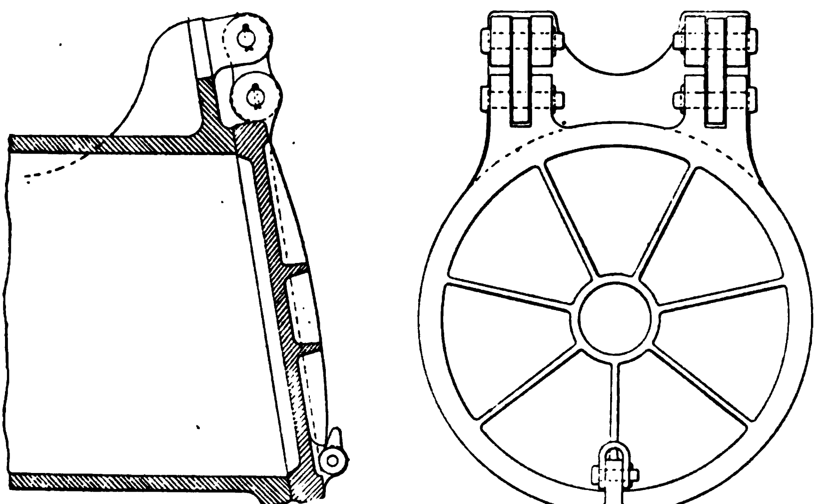


Fig. 18.—Flap Valve.

Flare, Flaring.—The enlargement of a cylindrical object at the mouth. It is a term used by coppersmiths and tinsmiths, and is the equivalent of bell-mouthing.

Flash Boilers.—The chief advantages that the flash boiler possesses are (*a*), practically perfect safety, (*b*), rapidity of steaming, (*c*), the production of superheated steam without auxiliary apparatus, (*d*), absolute freedom from scale, and (*e*), small space occupied.

Taking these points in the above order:—Safety is assured by the fact that it is necessary to employ tubes of such a thickness, in order to form a heat reservoir, that bursting is practically impossible. Even in the event of a tube giving way there is no danger; the effect is the same as when an hydraulic main bursts; the moment the pressure finds an outlet it ceases to exist. The writer has had the experience of being on an automobile fitted with a flash boiler, when owing to the relief valve having been tampered with, one of the tubes burst. The steam pressure at the time was well over 1,200 lb. per sq. in., but beyond some of the burners being extinguished by the sudden puff of steam, no damage was done to either the car or the occupants.

Rapidity of steaming is a characteristic which this type of boiler possesses in a marked degree. It is possible, and even usual, to raise the pressure from zero to over 800 lb. in less than a minute. Moreover, provided there is a good fire the pressure is maintained so long as water is supplied to the boiler.

The degree of superheat of the steam depends entirely on the design of the boiler and the connections of the various coils. For automobile work the coils of tube are usually so connected that the superheat is very high. What it is in degrees Fahr. is not easy to say exactly, but probably it ranges as high as 1,700° or even more. At such temperatures all ordinary rules for the flow of steam through pipes become useless. The steam behaves more as a perfect gas in its mobility. For instance, for supplying an engine with two double-acting cylinders of 6-in. bore by 6-in. stroke, a steam pipe with a $\frac{5}{8}$-in. bore was found more than ample in size. The throttle was never more than half open, whereas with saturated steam such a pipe would have been far too small. Cylinder condensation is quite unknown after the first few moments of running, whence it has been found that there is little or no economy in the use of compound engines. All the expansion necessary can be carried out in one cylinder with very little loss. On small engines, as used for motor car propulsion, the cut-off is frequently as early as $\frac{1}{12}$ of the stroke. It is far from uncommon to find

the steam pipe at a bright red heat, and that this is not due to heat conducted along the metal from the boiler is proved by the fact that the fire can be full on for a considerable time without the pipe being more than comfortably hot to the touch. Within a few seconds of the opening of the throttle valve the pipe rapidly becomes bright red, thus showing that it is the steam which heats the pipe. With such a superheat it is possible to get as great economy with small engines as is to be had with large Corliss mill engines.

Owing to the scouring action of the highly superheated steam through the tubes these are very seldom troubled with scale. The writer has tested the point by operating a flash boiler with strong brine as feed water, but no scale was formed in the tubes. A separating drum was required to allow the powdered salt to drop out of suspension before admitting the steam to an engine, but otherwise no difficulties were apparent. From this it would appear that the flash boiler would be of great utility for marine work, especially where space is limited (as in torpedo boats), as all need for fresh water is done away with. Oil does not appear to have the slightest influence, good or bad, on the action of these boilers. It is only necessary to keep the feed water free from grease for the sake of the feed pump valves.

As an example of the small space occupied by flash boilers there may be instanced the following:—

The outside dimensions of a boiler casing were 3 ft. 4 in. wide, 1 ft. 9 in. deep, and 3 ft. 1 in. high. The tube coils contained in this case were as follows:—

A feed-heating coil around the inner surface of the fire-box, made up of 30 ft. of $\frac{13}{16}$-in. bore tube. Three lowest coils each of 33 ft. of $\frac{5}{16}$-in. bore; the centre three coils each 33 ft. of $\frac{9}{16}$-in. bore, and the top four coils each 33 ft. of $\frac{7}{16}$-in. bore; the total heating surface being 85 sq. ft. Water is fed to the feed heating coil which surrounds the inside of the fire-box, thence it goes to the top $\frac{5}{16}$-in. coil, and descends through these three coils to the lowest. From the outlet of this the wet steam is led to the top coil of all ($\frac{7}{16}$-in. bore), and descends through all the remaining coils in regular succession, till it issues from the lowest of the three $\frac{9}{16}$-in. bore coils as highly superheated steam. To prevent any possibility of wet steam being delivered to the engines, a steam trap is fitted between the last of the $\frac{7}{16}$-in. coils, and the first of the $\frac{9}{16}$-in. bore coils, by means of which all water is separated from the steam. The weight of the boiler in working order is $7\frac{3}{4}$ cwt. and it is easily able to steam an engine of 60 I.H.P.

The following figures are the result of a long test of the boiler while steaming a pair of 6-in. by 6-in. double-acting engines. As the engines were not designed for use with highly superheated steam, the superheat had to be reduced by employing a live steam feed water heater through which all the steam supplied by the generator was passed on its way to the engine. The estimated superheat of the steam as it left the boiler was 1,270° Fahr., and the feed water was raised to over 400° Fahr. by the live steam heater before entering the boiler coils.

The boiler evaporates 1,309 lb. of water at a superheat of 800° Fahr. per hour. Evaporation per square foot of heating surface was 15·4 lb. per hour. Evaporation per pound of Russian oil, in the second hour of test was 14·2 lb. per hour. Working pressure during test, 550 lb. per sq. in. The hydraulic test (cold) was 4,000 lb. per sq. in., there being an ample factor of safety for the working pressure.

A second test was then made of the same boiler, but with an additional feed water heater using the exhaust steam from the engines. The evaporation per square foot of heating surface was increased to 20·3 lb. of water per hour, and the evaporation per pound of Russian fuel oil rose to 18·5 lb. of water per hour.

The oil burner used was of the "Hecla" or multiple jet type, and the oil was under an air pressure of from 45 to 55 lb. per sq. in.

All the joints between the various coils are outside the boiler casing, and they can all be inspected or tightened up while under steam. No joints of any description are out of sight or exposed to the action of the fire. The fittings are few, there being no water gauge or gauge cocks, no safety valve in the ordinary sense is fitted, but its place is taken by a steam-actuated relief valve in the feed water pipe line, close up to the boiler. The steam pressure

can be varied from 10 to 500 lb. or more, almost instantly.

From the above figures it will be understood that there is a considerable saving of space and weight as compared with the ordinary type of boiler, and the absence of water gauge and other fittings makes the boiler attendant's work very light. The working of the boiler as regards the water supply is practically automatic, and with the addition of a thermostatic regulator controlled by the temperature of the steam, the fuel supply can also be made automatic. Thus it is not impossible to have a fair sized steam launch with all the machinery directly controlled from the bridge, and it would only be necessary to have one man in the engine room to look after the lubrication and such matters.

As to the form given to the coils, the diagram, Fig. 19, shows the usual method of bending

Fig. 19.—Flash Boiler.

these. By reversing each alternate coil, the tubes of one come over the spaces in those adjacent to it, as shown by the dotted lines. The feed pump is continually at work, and any excess of water is bye-passed back to the water tank by the steam actuated relief valve, only as much water is fed to the boiler as is required for the work being done by the engine. This feed pump is usually driven by the main engines, but for large boilers there are advantages gained by employing a separate engine for the pump. Thus when first starting the boiler, the small engine is more easily turned round by hand till sufficient water has been forced into the boiler to make steam enough to run the pump engine. Also the stopping of the main engines does not stop the feed pump, so that there is always plenty of steam available for re-starting the engines. The feed may be regulated by controlling the speed of the pump engine as well as with the relief valve.

A safety valve on the steam pipe is advisable for use in emergencies, as under certain circumstances the pressure will run up to a very high figure almost instantaneously, as for instance when the boiler is working at, or near, its maximum capacity and the engine is suddenly stopped. In this event the pressure will rise in a few seconds to an alarming extent provided the fire is good, and no relief valve is fitted. The writer has experimented with a steam car of his own design (flash boiler) having an ordinary screw down stop valve, hand operated, in lieu of a safety valve proper. This stop valve when opened allowed the water in the boiler coils to return to the feed tank, being connected to the feed pipe in between the check valve and the boiler coils. When the car was running the steam pressure normally stood at 400 lb. Immediately the throttle valve was closed the pressure gauge needle ran around the dial till it pressed hard against the stop pin at the zero end of the scale, and was bent. This gauge read to 800 lb. and there was the usual gap between the two extremities of the scale. Considering this gap, and the force required to bend the needle, the actual pressure could not have been far short of 2,000 lb. per sq. in., and this was reached in less than thirty seconds after closing the throttle valve. As a rule the hand relief valve was opened simultaneously with the closing of the throttle, so that the pressure seldom rose over 500 lb.

When working with such high temperatures as are usual with flash boilers many curious facts are observed. The temperature of the steam is in no way dependent upon the pressure as in ordinary practice. It is frequently the case that the temperature will be well over 1,000° Fahr. with only 5 lb. pressure, while at other times the pressure will be 800 lb. or more, with a temperature below 700° Fahr. It may seem to be a paradox, but in practice it requires less surface to condense highly super-

heated steam than for saturated. The writer noticed that as long as the boiler of his car was delivering "red hot" steam, only water was discharged from the condenser outlet. When by reason of the fire being low, or the boiler being overloaded, saturated steam passed through the engine, the condenser discharged less water but showed steam. On the occasion of a test of a fairly large flash boiler in a room of less than 1,200 cub. ft. contents, there was no trace of moisture on the windows or walls, although the steam from over 180 gallons of water was exhausted from the engine directly into the atmosphere in the room. The external temperature was not much above freezing, yet the windows were hardly at all obscured. Those who were present at the test complained of pronounced drowsiness, and this, in conjunction with the absence of moisture of condensation, would appear to indicate that the water was disassociated into its constituent gases.

Engines intended for use with highly superheated steam should be designed on gas engine lines. Stuffing boxes, slide, and piston valves are all inadmissible. Trunk piston, and poppet valves work well if suitable lubricating oil is employed. The valves are operated by cams in the usual manner, but the cam shaft is adapted to be moved along to bring either of two sets of cams into operation, for forward and backward running, respectively. Alteration of cut off is easily effected by so forming the steam admission cams as to permit of the valves being held open for a longer or shorter period according to the position of the cams with respect to the valve spindles. The cams are made to open the steam valves always at the same point of the piston stroke, while the "trailing" side of the cams is made spirally to alter the time the valve remains open. For a superheat of from 800° to 1,000° Fahr., the ports and passages for the steam may be about one-half the area usually allowed for saturated steam, owing to the much higher speed with which superheated steam will pass through the ports. For the same reason all joints must be perfectly steamtight. A very small leak will reduce the pressure to a much greater extent than would be thought possible.

At the present time there are no reliable rules and formulæ for flash boiler design such as we have for ordinary boiler practice. Many experiments are necessary before a really satisfactory plant can be designed as things stand at present, but the flash boiler is just as capable of being reduced to a scientific basis as any other type of steam generator, instead of being a matter of trial and error as it is to-day.

Flash Point.—Denotes the temperature at which an oil or fat bursts into flame. *See* **Oils, Tempering.**

Flask.—A **Moulding Box.**

Flat-Bit Tongs.—*See* **Smiths' Tools.**

Flat Ends, or Flat Surfaces.—This has reference only to the strength of such surfaces when unstayed. When flat surfaces are stayed the strength due to staying has to be estimated. Flat unstayed surfaces are used commonly for the covers of steam domes, and the shell crowns and furnace crowns of vertical boilers and other vessels. The alternative is cambered ends, or **Dished Ends,** which are stronger. There are three conditions of pressure possible:—(1) That of a flat plate supported round its edges and uniformly loaded. (2) That in which it sustains a concentrated load about the centre, neither of which conditions hardly occur in practice. (3) That in which a plate uniformly loaded is fixed encastre round the edges. This is the only one applicable to boiler work, though not quite the same as union by a flanged joint.

Unwin's formulæ are—

$$f = \frac{2}{3} \times \frac{r^2}{t^2} \times p$$

$$t = \sqrt{\frac{2 \times r^2 \times p}{3 \times f}}$$

$$p = \frac{3 \times f \times t^2}{2 \times r^2}$$

Where f = maximum stress.
r = radius.
t = thickness.
p = pressure in lb. per sq. in.

Dr Grashof's formulæ are—

$$t = C \times r \times \sqrt{p}$$

Where t = thickness of plate.
r = radius of plate.
p = pressure in lb. per sq. in.
C = constant =
·01633 for cast iron.
·010541 for wrought iron.
·0081649 for steel.

To obtain the working pressure in lb. per sq. in.,

$$p = C \times \frac{t^2}{r^2}$$

Where C = 3,750 for cast iron.
= 9,000 for wrought iron.
= 15,000 for steel.

Mr Cherry's formulæ take account of the maximum safe test pressure.

P = the maximum safe distributed test pressure in lb. per sq. in.
r = the radius of plate.
t = the thickness of plate.

For wrought iron—

$$P = 60{,}000 \times \frac{t^2}{r^2}$$

$$t = \cdot 0041 \times r \times \sqrt{P}$$

$$t^2 = \cdot 000017 \times P \times r^2$$

For mild steel—

$$P = 80{,}000 \times \frac{t^2}{r^2}$$

$$t = \cdot 0036 \times r \times \sqrt{P}$$

$$t^2 = \cdot 0000125 \times P \times r^2$$

The above formulæ make the strength of plates vary directly as the square of the thickness, and inversely as the radius. Experiments by Mr R. Wilson and Mr Nichols did not justify these, and they gave a higher strength than the formulæ do.

These experiments were conducted on flat ends attached to a cylindrical shell 2 ft. 6 in. diameter. In one case a flanged end $\frac{3}{8}$ in. thick was tested to bursting. At 25 lb. there was a deflection of $\frac{1}{8}$ in.; at 50 lb., of $\frac{1}{4}$ in.; at 65 lb., of $\frac{3}{8}$ in. Until 65 lb. there was no permanent set on removal of the pressure, when it amounted to $\frac{3}{32}$ in. At 300 lb. the plate burst, with a permanent set of $1\frac{3}{4}$ in.

The practical issue is that flat unstayed plates are not to be used for any but small areas, but if unstayed, dished or cambered ends must be adopted.

A flat plate is subject to incessant deflections under pressure and release therefrom, which result in grooving, even though the elastic limit is not passed. Hence the importance of stayed plates.

The problem of the strength and elasticity of a flat end is affected by the method of its attachment. It is a question of avoiding the extremes of too great rigidity, and of too great elasticity. A rigid plate is not suitable for some situations in which other parts are attached to it that will be subject to variations in length due to changes in temperature; the end plates of Lancashire and Cornish boilers, for example, to which the furnace flues are attached; and the crown plates of vertical boilers, which must yield before the expansion of the uptake and fire-box. For these reasons a flanged attachment is better than an angle iron ring fastening. But to secure the fullest advantages of flanging, the flange must be turned with a large radius, say from $1\frac{1}{2}$ in. to 2 in., being equal to from three to four times the thickness of the plate. Then as the plate alternately bulges and flattens with alteration of temperature, there is no narrow annular area of metal subject to excessive local bending, as with an angle iron ring mode of attachment, but the bending stresses are distributed over the convexity of the flanging.

For this reason angle rings are never now used for the attachment of the crowns and shells in vertical boilers. And the practice of fastening the back end plates of Cornish and Lancashire boilers to their shells with angle rings is much less frequently adopted than formerly.

Flat File.—*See* **Files.**

Flat Gouge.—*See* **Gouge.**

Flat Ramming.—Finishing the surface of a mould with a rammer having a flat face, following the detailed consolidation of the sand done with a pegging rammer.

Flat Rope.—*See* **Wire Ropes.**

Flats, or **Flat Bars.**—Rolled bars of iron or steel of rectangular, but not square sections

Flattening Plates. — Plates have to be flattened by the plater and boiler-maker before they can be worked up into plane portions. They are treated either by hand or in the **Flattening Rolls**. The first is the older and less satisfactory method, though still of necessity largely adopted; the second is better in all respects.

When a plate becomes bent, that is because the concave side is shorter than the convex one. It is therefore useless to hammer the convex

side with the idea of bending it back. The other side must be struck in order to extend the metal, and force it to unbend of its own accord. So that flattening a plate is not primarily a bending operation, though bending is the result obtained.

Plates are seldom buckled or curved uniformly, but in places, and the parts adjacent enclose the buckle. The remedy then is not to hammer on the buckle, but on the adjacent parts, and so by extending these to leave the buckle freedom of movement.

As the amount of stretching is extremely minute, it is easy to see that by injudicious and excessive hammering the last state of a plate might become worse than the first. A disadvantage, too, is the possible injury to the plates set up by the hammer blows. This cannot be avoided by heating the plates, because they could not be straightened while hot. This is an argument for flattening in rolls. Here the action is similar to that of bending. The forces operate over a large area, and the metal is coerced without concussion, or local indentation of the metal.

A good deal can be done in the ordinary bending rolls in the partial straightening of plates. The worst of the kinks can be taken out thus, leaving less work for the hammer on the levelling block.

Flattening Rolls, or **Mangle**, or **Plate Straightening Machine**.—A machine used for straightening plates by passing them between a series of rolls, generally three below and four above. The top rolls are usually the adjustable ones, but sometimes the lower ones are. Three passes generally suffice to straighten a plate. The first two passes camber the plate, the first in one direction, the second in the other, the third straightens. Sometimes two passes, the second being the straightening, suffice. Many machines of this kind combine provision for bending as well as straightening, by making some of the rolls removable.

Fig. 20, Plate II., shows a plate-flattening machine by Francis Berry & Sons, having seven rollers, four of which are adjustable and can be raised or lowered together, or the two outer ones can be raised and lowered separately. The three driven rollers have pinions keyed on their ends. All the handles and levers are brought to one end, so that the workman has complete command without shifting his position.

Flatter.—*See* **Fullering, Smiths' Tools**.

Flat Turret Lathe.—A special type of lathe, in which instead of the ordinary turret with tools held in horizontal holes, and against vertical faces, a flat horizontal turn-table kind of support is employed, upon which the tool holders are clamped, a feature possessing certain advantages.

Figs. 21 and 22, Plate II., show the Hartness flat turret lathe, with the cross-sliding head, a new feature added to enable wide facing operations to be performed, by feeding the head across, while a tool held in the turret remains stationary. A single belt pulley drives the headstock spindle, through a set of change-speed gears, enabling a large range of speeds to be obtained. The turret is fed up either by hand, or power, stops being fitted to arrest the travel at predetermined points. The turning tools used are of the "box" form, with vee-guides, and the screwing dies are of the opening type.

Fleming & Ferguson Boiler.—A water-tube boiler designed specially for the merchant service. Its principal feature is that the steam drum is made sufficiently large, and the tubes short enough to permit of withdrawing and replacing the tubes within the diameter of the drum. The boiler belongs to the accelerated circulation type, most of which have a fundamental resemblance in the possession of two smaller water chambers connected with tubes straight or curved to the upper or steam drum. In the Fleming & Ferguson these tubes are curved outwardly on each side of the axis, joining the upper and lower drums. Both banks of tubes cross to some extent; an increased spacing at the upper ends provides for this overlap of tubes. Around this central design many modifications have been made. The number of bottom drums has been increased, boilers are single or double-ended, and grates run longitudinally or transversely.

Flexible Coupling.—*See* **Universal Joint**.

Flexible Shaft.—A device used for driving portable tools, for drilling, tapping, grinding,

tube expanding and beading, &c. The Stow shaft consists of a number of coiled wires one within another, running in a flexible outer covering, so that the whole may be bent without affecting the rotations. At one end the revolving centre is driven either by a rope-pulley, or by electric motor, and is connected at the other to the drill or other tool being operated. A suspension frame holds the rope-pulley end steady, by means of a counterweight. The flexible shaft is then moved about to any position within its range. The revolving section must be well greased with tallow or lard, or animal oil.

The Wicksteed shaft comprises a number of flexible or universal joints connecting short lengths of shaft, running within a flexible metallic cover, oil being contained within the latter.

Flexible Tubing.—This is employed in cases where a non-rigid connection must be made between supplies of water, steam, gas, oil, air, &c. The hose is variously made of rubber, and rubber with compositions, leather, canvas, asbestos, and the flexible metallic (bronze or steel) tubes. Protection is afforded when necessary, as mentioned under **Armoured Hose**, except in the case of the metallic kind, which is self-protective. Pressures up to 350 lb. per square inch can be withstood.

Flitch Beam.—A beam, Fig. 23, consisting of a balk which has been sawn through the heart and bolted together again with the heart portion turned outwards, and a wrought-iron plate inserted between the halves. The turning of the heart portion of the wood outwards allows more thorough seasoning than is possible in a solid balk, and consequently the timber keeps sounder and more permanent in form; besides which there can be no unseen interior defects, such as heart shakes. Since the introduction of steel girders flitch beams are not often employed.

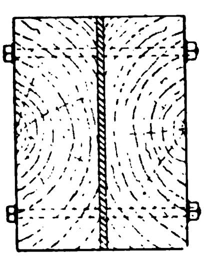


Fig. 23.—Flitch Beam.

Float Cut.—*See* **Files.**

Float Gauge.—An old form of low water gauge employed in egg-ended and wagon boilers. Also used in tanks to indicate the height of the water. The chain to which the float—of wood—is attached is brought over a pulley, and a pointer at the other end moves on an index.

Floating Crane.—Floating cranes are constructed over a wide range of powers and types according to the special service required. The largest class is fitted on board a self-propelling vessel, and has hoisting, revolving, and derricking motions. Its lifting power sometimes attains 100 tons, and its dimensions are such that it may range alongside and plumb the centre of the largest steamships. The work of such a crane is to deposit boilers and machinery on vessels undergoing repair, or to place heavy cargo on board a vessel without the necessity of bringing her to a special wharf for that purpose; in this way a steamer may receive cargo whilst still under the coal tips. Such cranes are made with or without variable ballast, which may take the form of either rolling weights, or ballast tanks and suitable pumps.

A different class of floating crane, but still of considerable capacity, is used in harbour construction, and consists of a fixed jib at one end of a pontoon. There is no revolving or derricking motion, all movement required being obtained by manœuvring the pontoon; hoisting gear is of course provided. The work of this type of crane consists chiefly in depositing the concrete blocks of a breakwater, and removing large boulders met with in dredging, &c.

A smaller class of floating crane is used for dredging rivers and channels, for coaling lighters, &c. It is usually an ordinary fixed steam crane on a rectangular pontoon, and fitted with hoisting, revolving, and derricking motions; if it is to be employed for dredging, a suitable grab or excavator is used according to the nature of the material to be handled.

Floating Docks. — A floating dock is a structure of iron or steel plates forming a series of watertight compartments which can be filled with water to sink it, and emptied again by pumps to raise it. When the dock is sunk, the vessel to be docked is floated over it, or the dock is towed under the vessel, and as it rises it carries the vessel up with it. It is not

essential, therefore, that the dock should be anything more elaborate than a rectangular platform or pontoon having sufficient depth to give the displacement required to raise the weight of the largest vessel it is intended to take. It is very desirable, however, for several reasons, always to include sides standing up to a considerable height above the base. Sometimes only one side is employed, forming an L-shaped structure, but more often there are two. These also are in box form, divided into compartments. Their tops are about 5 feet above water when the dock is sunk to the fullest extent it is designed for. They serve as guides in raising and lowering the dock, and also strengthen the base, and form walls for centring and shoring the vessel from. The ends of the dock are left open. Generally the ends of the base are pointed or rounded to facilitate towing the dock through the water, and to give additional length over the line of keel blocks.

Fig. 24, Plate II., shows the Bermuda dock carrying the *Sans Pareil* of 10,470 tons. The lifting power of the dock is 16,500 tons. It carries two travelling cranes seen in the view.

Fig. 25, Plate II., is a depositing dock at Barcelona, of 6,500 tons lifting power, and a length of 366 ft. 11 in. On the left a vessel is seen transferred to the gridiron, while the dock itself is carrying another vessel.

The object of dividing these structures into a great number of watertight compartments is not only to avoid danger through outer leakage, but mainly to prevent a general flow of water to one corner or part that happens to tilt lower than the rest. This, if allowed to occur, would speedily become worse through continued flow in that direction. Even though fitted with compartments, the dock is liable to get out of level through unavoidable inequalities in the withdrawal of water, and when this occurs it is necessary to close the valves of the part that is rising too quickly, and thus enable the level to be regained.

Floating docks have advantages which will probably eventually result in their greatly outnumbering the older type of graving dock. They are cheaper in working and more expeditious. They can be taken to a ship if necessary, and placed under it, even when the vessel is too low in the water to enter a graving dock, nominally of similar capacity, but without sufficient depth of water to take the ship except at its normal draught. The floating dock is not limited at all in length, nor in the one-sided type is it limited in beam. The maximum weight that it will fully lift cannot be exceeded; but very often, if necessary, a much heavier vessel than it is designed for can be raised sufficiently far out of the water in order to effect the repairs or inspection desired. There is an example of this in the Barrow dock, which was used to partially lift the *Empress of China*, a vessel weighing considerably over 1,000 tons more than the dock was normally designed for. In this instance it was merely required to raise the propellers above water. The most notable feature of this case, however, was that the length of the dock was only 242 feet over the blocks, while the length of the vessel was 455 feet, or nearly twice as much. This involved a great deal of overhang at the ends, but the lifting was done without injury either to the vessel or the dock. This, of course, is an extreme case, but vessels considerably longer than the docks have frequently been raised, and it is found that the overhang does not strain them perceptibly. In many cases, also, especially in warships where quick manœuvring is required, the keel is often not more than half the length of the ship over all. Unless this overhang can be supported in some way there is no advantage in having a dock the full length of the vessel.

In a graving dock the entire length must be enclosed, and the amount of pumping required to empty the dock, and the further continuous pumping required to keep it drained, is much greater than that required for emptying the compartments of a floating dock. When the docks have to be emptied without containing a vessel, the graving dock, of course, has its maximum amount of water, while the floating dock, having only its own weight to raise, requires comparatively little removed.

In localities where there are very great variations in the water level, owing to floods and droughts, or exceptionally high and low tides, it is difficult to construct a fixed dock that will be available for use at all times, and in such localities the floating dock has to be employed.

On the other hand, in localities where there is no tide the difficulties of constructing a graving dock are great because of the wet ground. Around the coast of the United Kingdom the best conditions for graving docks exist, and we consequently look upon them as the natural type, and have them in far greater numbers than floating docks. On the German coast, where there is no tide, floating, and graving docks exist in about equal numbers. In America the floating type of dock predominates.

Floating docks are usually berthed in a dredged-out basin and kept there permanently, but they can be tugged any distance, and be used in open water if required. Ships cannot be docked in rough water because of their own unsteadiness, but the dock itself, owing to its large submerged area, is always steady. A method adopted with some floating docks moored in the roadstead at Valparaiso is to close with a bulwark the ends facing the sea. This gives smooth water inside the dock, in which the vessel remains steady while the dock is rising.

As floating docks are generally kept constantly on one site there is not as much necessity for frequently cleaning their underwater portions as there is for cleaning the bottoms of vessels which are required to travel through the water with as little resistance as possible. To prolong their life, however, it is necessary that they should be periodically examined everywhere, repaired and painted. To do this they must be of a self-docking character. The outside may be got at by tilting, and manholes should be provided to give access to all interior parts. As regards permanency, the floating dock must of course rank inferior to a stone dock, but it is permanent enough for practical purposes.

The main objection to floating docks has been a doubt whether they were sufficiently rigid to carry a vessel without injuriously straining it. In practice, however, no trouble of the kind has occurred, and if it had, it would not be difficult to make a floating dock practically as rigid as a graving dock.

Flooring Boards.—These are usually 1 in. thick by 5 in. or 6 in. wide. The narrower they are the less trouble is there from shrinkage after they are laid. They should always be thoroughly seasoned before using. The laying of flooring boards is classed as joiner's work, the naked flooring being done by the carpenter. The boards are usually fitted together with square abutting edges, but are sometimes tongued or rebated in various ways. They are generally nailed down with flooring brads, sometimes directly through from the surface, sometimes secretly at the edges to conceal the brads. Occasionally in good floors screws are inserted, and the holes afterwards plugged. Sometimes the ordinary deal boards are nailed on the joists, and then a thin hardwood floor put on top in the transverse direction. These are excellent in machine shops, when maple is used, which does not absorb grease readily. End joints may be either square or splayed, and of course must always occur on joists, but an unbroken line of joints is never made on one joist.

Flooring Cramp.—A cramp employed for pressing the boards tightly together in laying floors. There are a number of forms of cramp used for the purpose, but the general principle of them all is first to obtain a ready and secure grip on one of the floor joists at the place desired, and then by means of screw or lever to exert pressure against the edge of the flooring board while it is being nailed, thus making the joints between the boards as tight as possible, and minimising subsequent opening through shrinkage.

Floor Plate.—A heavy plate of cast iron, planed, and tee-slotted, and mounted in the machine shop. On it massive pieces of work are bolted for operating on with machine tools, that can be shifted about the plate to suit circumstances. The plate is usually built up in several sections, because of its size. The Floor Boring machine is a modification of this idea, in which standards carrying a boring bar are mounted on a large plate, so that work of any awkward shape or size can be handled.

Floor Rest.—A tool rest used in many patternmakers' face lathes, in which the fast headstock turns round to face away from the lathe bed. The base of the rest stands on the floor, and is used when pulleys and wheels of several feet in diameter have to be turned.

Floors.—A floor is formed by laying boards

PLATE II.

Fig. 20.—Flattening Rolls, with Seven Rollers. Steam Driven.

Fig. 21.—Flat Turret Lathe. (Jones & Lamson Machine Co.)

Fig. 22.—Turret and Saddle of Flat Turret Lathe.

Fig. 24.—Bermuda Floating Dock, carrying the "Sans Pareil." (Clark & Standfield.)

Fig. 25.—Barcelona Depositing Dock, with Gridiron on left. (Clark & Standfield.)

To face page

on joists, the latter being arranged about 12 inches apart, and transversely to the direction of the boards. Often wood is discarded partially or entirely in favour of steel and concrete. Naked flooring is the framework on which the boards or other surface covering rests. This framework may consist of joists alone, or of joists supported by larger transverse members. Floors are divided into three classes—single, double, and framed.

Single Floors.—These are the simplest kind, and are only suitable for small spans. The naked flooring in this case consists only of the joists bridging from wall to wall, without intermediate support. Unless other considerations interfere, the joists are laid the narrower way of the room or building. In ground floors, their ends rest on offsets built up within the wall faces, and in upper floors they usually have to be inserted in pockets in the wall, air space being allowed around the ends to prevent decay. For spans of not more than 10 ft. or 12 ft., joists should be about 8 in. or 10 in. deep. The usual thickness is 2 in., sometimes more, but rarely less, because the line of nails holding the flooring boards might split a less thickness than 2 in. If there is any camber in the timbers they should be laid rounding side upwards. Knots also should preferably be in the upper part, because being then in compression they are not an element of weakness as they would be if in tension in the lower part.

When a plaster ceiling has to be attached to the under side of floor joists, they require to be more rigid than is actually necessary for the strength of the floor. If they are not so, there is risk of the plaster cracking. As a precaution against this, the ceiling laths are often not attached

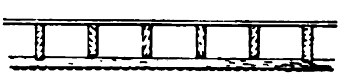


Fig. 26.—Floor with Ceiling Joists.

directly to the joists, but to light ceiling joists, Fig. 26, notched and nailed transversely to the under faces of the floor joists. Another advantage of this is that the passage of sound, which is very readily transmitted through the simplest form of single floor, is reduced by the employment of ceiling joists, which are generally made to come in contact only with every fifth or sixth joist, and clear the intermediate ones. As ceiling joists have little weight to support, they are seldom more than 3 in. deep by $1\frac{1}{2}$ in. or 2 in. wide in this class of floor.

Double Floors.—In floors of more than 20 ft. span, and often in considerably narrower ones, the floor joists rest on larger timbers called binders, Fig. 27, B. These are placed at intervals of 8 or 10 ft. transversely to the floor joists. In a span of 20 ft., for instance, there would be perhaps one binder B supporting the joists A in the middle of the span. Sometimes also to avoid

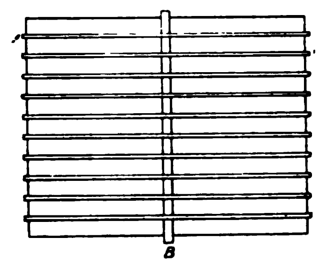


Fig. 27.—Plan of Double Floor.

contact of so many timber ends with the walls, the ends of the joists are supported on binders. Joists supported thus in the middle of a 20-ft. span do not require to be of larger section than for a 10-ft. span. As assistance can always be given in this way, the joists for floors of large area do not need to be of larger dimensions than those for floors of small area, and as the joists are so numerous it is found economical to keep them small, and add a few large members to support them.

Binders are often of rolled iron or steel in preference to wood. They are usually arranged to bridge the shortest distance between walls. The combination of binders and joists constitutes a double floor. Ceiling joists in this case are essential if a plastered ceiling is required on the under side, because the distance from binder to binder is too great to be covered by laths alone. The ceiling joists are about 5 in. by 2 in. and they usually fit between instead of being nailed across the under surfaces. In all cases, however, a slight projection below the other timbers of the floor is necessary to avoid broad surfaces where the plaster would not

hold well. When either the ceiling or floor joists to which the laths are nailed are more than 2 in. thick, narrower strips are often attached to their under surfaces to nail the laths to, thus affording a better key for the plaster.

Framed Floors.—In these the principle of the binder is repeated by adding still larger transverse members to support the binders. These larger members are called girders, Fig. 28, A, and are now usually of iron or steel, Figs. 29

Fig. 28.—Plan of Framed Floor.

and 30. Where the increased depth is not objectionable the binders B, Fig. 28, rest on top of the girders, but generally they are framed together in nearly or quite the same plane. This is done by fitting the binders between and supporting them by stirrups or brackets, and very often by tusk tenons if the girders are of wood. In this case the girders are generally flitched. The binders are always arranged to each side of the middle part of the girders, so that the latter shall not be strained more than can be avoided in the part where they are least able to support weight. Girders bridge the

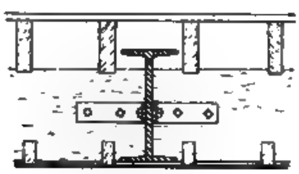


Fig. 29.—A Framed Floor with Wood Binders, and Steel Girder flush at the bottom.

shorter way of the span, and substantial support must be provided for their ends to bear on. This is also necessary, but to a less extent, in the binders of a double floor. The support should be solid from the ground, and never over door or window openings. In ground floors abutments can be built under the ends, and also supports at intermediate positions. In

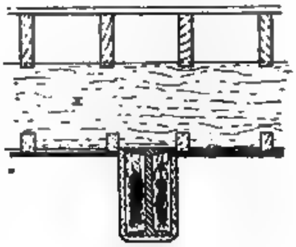


Fig. 30.—A Framed Floor with Girder projecting below the Ceiling, and boxed in with Wood.

upper floors, recesses or pockets, generally with arched soffits, are built in the walls, and wall plates or long templets of stone or iron are built in below to distribute the weight of girders and floor as much as possible. Girder ends, like binder and joist ends, are generally either cogged or dowelled on to the wall plates. Where girders are of great length, as is often the case in warehouses and factories, they are supported at intermediate positions by pillars or stanchions.

Trimming.—It is only in a very few cases that floor joists can be laid uninterruptedly

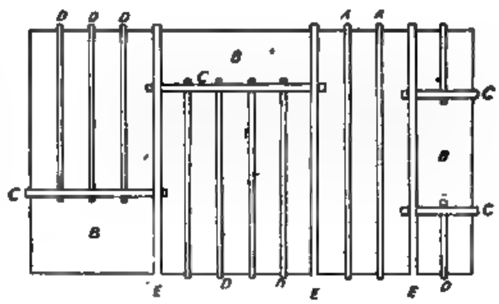


Fig. 31.—Trimming.

across the entire area of the floor. Openings to clear fireplaces, stairways, lifts, or flues in walls, are nearly always necessary. The shortening of the joists to provide these spaces is called trimming. The joists have to be cut away to leave the required space, and their ends have to be supported by transverse pieces called trimmers, which are of slightly stouter section than the joists themselves, their actual size depending on the number of joist ends they

have to support. The joists which support the ends of the trimmers are also thicker than the other joists, and are called trimming joists. When the trimmed opening is considerably longer in one direction than in the other, it is best to have the joists running the same way as the longest measurement of the trimmed space, because there are then fewer ends to trim. Tusk tenon joints are employed for trimming.

In Fig. 31, A, A are the ordinary, or bridging joists, B, B, B the openings, C the trimmers, D

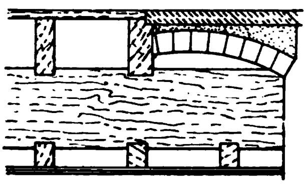


Fig. 32.—Brick Arch under Hearthstone to protect Wood-work from Fire.

the trimmed joists, E, E, E the trimming joists. Protection from fire is ensured by building a brick arch under the hearthstone, Fig. 32.

Strutting and Pugging.—At intervals of about 4 ft. transversely to the joists, lines of struts or braces are inserted between the joists to connect and prevent them from twisting. Herring bone strutting is the usual method. This consists in inserting diagonal struts side by side in opposite directions, extending from the top surface of one joist to the bottom of the next, as in Fig. 33. The struts are secured

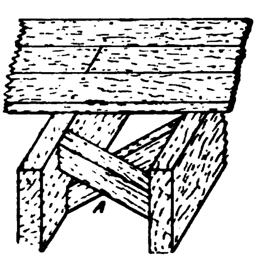


Fig. 33.—Herring-Bone Strutting.

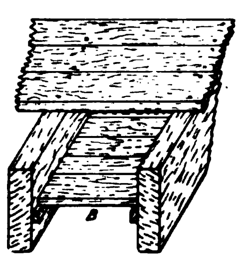


Fig. 34.—Pugging.

by skew nails. An alternative method is to insert pieces of wood the entire depth of the joists, and of the correct length to fit tightly.

Pugging is a method sometimes adopted for preventing the passage of sound through a single floor to the room below. It is generally done by the insertion of boarding, as in Fig. 34, on which is laid a quantity of rubble or other suitable material. Sometimes felt is put on the top surfaces of the joists before laying the boards. The employment of ceiling joists, however, with the fewest possible points of contact, Fig. 26, is more satisfactory than pugging, though not more effective in preventing the passage of sound.

Floors of concrete surface, or wood blocks on concrete, are very common. The floors used in the machine shops of Ludw. Loewe & Co. at Berlin are made in two thicknesses of timber, laid on steel joists. The joists are filled in with cement concrete, in which pine sleepers are embedded. To these, pine sleepers 2 in. thick, tongued and grooved are nailed, and over these narrow maple boards $\frac{7}{8}$ in. thick by 3 or 4 in. wide are nailed crosswise. Maple is hard, tough, and clean, and is not easily splintered. Cement is used for the floor of the smithy. There are innumerable methods of constructing such floors, but the components are steel and concrete arranged so that the metal takes the tensile stress, besides binding the concrete together. *See* **Armoured Concrete, Expanded Metal, Troughing.**

AVERAGE LIVE LOADS ON FLOORS.

(*Redpath, Brown, & Co., Ltd.*)

	Per sq. ft.
Crowd of people - - - -	80 to 100 lb.
Floors of dwellings and offices -	90 „ 112 „
„ „ public halls, churches, theatres, &c.	100 „ 150 „
„ „ warehouses - -	150 „ 300 „
„ „ workshops carrying heavy machinery -	200 „ 400 „

In calculating the stanchion loads in high buildings where a number of floors have to be supported, the maximum load on the lower lengths may be frequently safely assumed as considerably less than that due to the full load on each floor, since it is very unlikely that all the floors will be fully loaded at the same time.

WEIGHTS OF FLOORS, &c. (average).

	Per super. ft.
Light timber flooring and joists	6 to 10 lb.
Heavy " " "	10 " 15 "
Plaster ceiling - - - -	2 " 5 "
Concrete slab flooring, per 1 in. thickness - - - -	10 " 15 "
Tubular or hollow fireproof flooring, complete - - -	28 " 50 "
Light steel framed and sheeted roofing - - - -	5 " 8 "
Steel or timber framed and slated roofing - - - -	12 " 18 "

Floor Work.—That section of moulding which is done on the foundry floor. It comprises by far the larger quantity in the average iron foundry, while in brass foundries bench work predominates, and in machine moulding the only floor work is the actual closing and pouring of the moulds.

Floor work is unavoidable in heavy moulding. While ramming, men stand, but nearly all mending and cleaning-up, coring, and runner and riser cup making, &c., must be done while in a kneeling posture. Often mending up and cleaning have to be done lying on the back with the mould swung overhead in the crane. In work of medium dimensions the increase in machine moulding, and the growing use of snap flasks, will lessen the floor work.

Flow of Liquids.—*See* **Hydraulics.**

Flow of Metals.—A term due to the researches of M. Tresca on lead and similar metals which under sufficient pressure exhibit the phenomena of liquids under pressure, as contraction of area at an orifice, and curving round obstacles, and being thrust laterally as a portion of a punching burr is thrust sideways into the plate. The phenomena apply to all metals and alloys not actually brittle. Under great pressure slowly applied they behave as perfectly plastic materials but without any change in density. The application of this knowledge lies in forged work, in extruded metal, and allied processes where compression is exercised.

Flues.—These are furnace, or smoke flues, the first internal, the second external. Furnace flues are of iron or steel, the smoke flues are in brick-work. The actual furnace occupies only the area of the grate bars in the first-named, the remainder is a combustion chamber. Flue plates are the ends of a Cornish or Lancashire or Scotch boiler, to which the furnace flues are riveted. Flue surface is the area of the flues exposed to the hot gases.

Fluid.—A substance which yields to pressure. Fluids at rest must sustain equal pressures in all directions. Fluids are liquids or gases.

Fluid Compressed Steel.—A method of producing practically sound steel ingots free from blow-holes and cracks, the successful accomplishment of which was due to the late Sir Joseph Whitworth. The first attempt made was to produce the compressed ingots for guns with a central core, but that was abandoned for the present method of casting solid, and boring the hole. The molten metal is pressed with a ram under not less than 2 tons to the inch. The mould is placed on a truck which is run under the press, and thrust up against a plug fixed to the crosshead above. The mould is built up of forged steel hoops, lined with cast-iron bars with radial grooves and vertical chamfers at the back for the escape of the gases, and lined with refractory material of about $\frac{3}{4}$ in. thick. The bottom and the plug are faced with fire-brick.

The effect of compression is to drive out large quantities of gas, and to compress any that remains into a small compass. The ingots become shortened by about $1\frac{1}{2}$ in. per foot.

Flume.—A trough or channel which conveys water to a waterwheel or turbine.

Fluorine.—Fluorine, (F. 19), occurs in fluorspar or calcium fluoride, CaF_2, and cryolite, $3NaF + AlF_3$. It is obtained as a colourless gas by the electrolysis of anhydrous hydrofluoric acid, HF. No compound of fluorine and oxygen is known, which is rather remarkable, as fluorine eagerly unites with nearly all other elements and decomposes most compounds. Its compound with hydrogen, hydrofluoric acid, is valuable commercially owing to its power of eating into glass, and so etching designs, letters, or figures.

Flush.—A common term which signifies that adjacent parts are all in line or level. A flush bolt is one, the head of which is sunk into a hole countersunk or arbored. A locomotive boiler is flush topped when the top of the fire-box casing is in line with the top of the barrel.

Fluted Columns.—The moulding of fluted columns requires a composite pattern, in which the flutes, with the necessary wood to back them up, are made in sections distinct from the main body. The body may be of wood, lagged up in the usual way; or when quantities are required; in cast iron, planed to receive the flutes, Fig. 35. The jointing of the latter should not be done radially, but in the direction indicated by the dotted lines *a* in Fig. 35. The reason is that the flutes will deliver from the sand better. There must be no undercutting, and the number of sections required will depend on the delivery practicable. The thumb screws and plates shown are to permit of loosening from the main body of the pattern; this is an alternative to the use of wood screws which work loose in the timber with service.

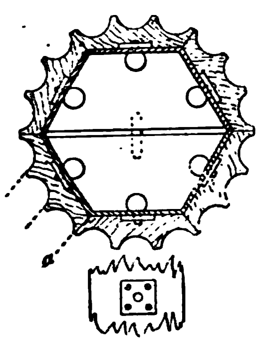


Fig. 35.—Fluted Columns.

Flux.—A substance added to the charge of smelting and re-melting furnaces, which has the property of forming a fusible compound with earthy matters as silica, or clay. These, apart from the flux would mingle with the metal and injure its qualities. Some few ores are self-fluxing. The nature and quantity of the fluxes used in any given furnaces have to be governed by the composition of the ores. Fluxes are used by smiths and others to dissolve metallic oxides, the presence of which would prevent perfect welding, or soldering.

Fly Cutter.—A single-edged cutter mounted in a bar or head, and used chiefly in cases where the expense or trouble of making a complete circular cutter has to be avoided. It is very useful for milling profiled shapes, including gear teeth, for experimental purposes, since the steel can be filed up quickly, and alterations made easily if necessary.

Flying Machines.—There are two systems of aerial navigation, (*a*) that in which an inflated gas bag sustains the weight of the car, and motor and propellers by which the whole is moved and directed; and (*b*) that in which a gas bag or other attempt at making the apparatus lighter than air is discarded, the machine rising and being propelled by aeroplanes. Strictly speaking, the latter only are flying machines, the former being dirigible balloons.

Expert opinion is now almost unanimous in recognising the great limitations of the dirigible balloon, and the future certainly lies with the flying machine proper. Any type of balloon is too much at the mercy of the wind. Great things have, however, been done with such airships by Zeppelin, Santos Dumont, and Stanley Spencer. Count von Zeppelin's cigar-shaped airship measured 415 ft. in length and 40 ft. in diameter. The framework was largely constructed of aluminium, and the body of the balloon was subdivided into seventeen separate and independent balloons. It was propelled by two 15 HP. Daimler motors, the propellers working at the rate of 1,200 revolutions per minute. Zeppelin obtained a speed of 18 miles per hour before he sold his invention to the German Government. On 19th October 1901, Dumont performed the wonderful feat of sailing from St Cloud to and round the Eiffel Tower, returning to the spot from which he ascended in thirty minutes, and thus winning the prize of 100,000 francs offered by M. Henri Deutsch. Propulsion in the Dumont airships was accomplished by petroleum motors; the screw measured 4 metres in diameter, and machinery and basket were suspended from the elongated balloon by piano wires. On 17th September 1903, Spencer navigated the "Mellin" airship from the Crystal Palace to the dome of St Paul's. In the "No. 3 Spencer airship," the cigar-shaped bag measured 84 ft. in length, and 32 ft. in diameter, and held 40,000 cubic feet of coal-gas; the screw propeller or tractor (11 ft. in diameter) was actuated by a 5 HP. Simms' petrol motor; steering was accomplished by a rudder sail at the stern.

Another huge airship was designed by Dr F. A. Barton and Mr F. L. Rawson, a successful trial taking place in 1905. The balloon was 180 ft. long and 40 ft. in diameter; it had lifting capacity of over 5 tons; contained 170,000 cubic feet of gas; and was also remarkable for the fact that it possessed a series of thirty aeroplanes between the long deck and the bag. Yet the airships of these experts, with all the advantages of modern motors of almost insignificant weight per HP., of light materials, and of wider knowledge of aerostatics, have failed to stand against a strong wind as did the earlier airships of Giffard (1852), Dupuy de Lôme (1872), Tissandier (1884), Renard and Krebs (1885), and Schwarz (1897). The usefulness of the dirigible balloon is thus limited to calm weather, and even then the conditions of success are: (1) that the size of the balloon must be great, yet (2) must offer the minimum resistance; (3) the motor must be of very great power compared with its weight.

The principle of the flying machine is seen in the flight of an ordinary kite—a plane surface inclined at an angle rises when drawn through the air, the string of the kite being supplanted by the motor of the flying machine. Investigations into the proper angle for these plane surfaces or aeroplanes, the lifting power of the air at different angles, the proportion of surface to the total weight, and more important still, the question of regaining disturbed equilibrium, have been made by means of "gliding machines." These possess no motor, their inventors considering that the questions just mentioned need a fuller investigation before applying artificial power. They are launched from a height and, parachute-like, glide earthwards. Lilienthal, a German engineer, carried out a series of gliding experiments in the nineties, using concavo-convex wings, like those of a bird, in preference to planes. His last machine weighed 50 lb., making with his own weight, 220 lb.; the relation of surface to weight was about $\frac{3}{4}$ sq. ft. to 1 lb. He was killed in experimenting (1896) by a powerful current of wind upsetting the equilibrium of his machine. Pilcher, an Englishman, was killed (1899) in a similar way.

Of machines fitted with aeroplanes and driven by a motor, those of Professor Langley in America, and Hiram Maxim in England stand first. Langley's machine weighed in all 30 lb., and was propelled by a steam engine of 1 HP., weighing 7 lb., thus sustaining a weight of 30 lb. per HP. The surface measured 70 sq. ft. On two occasions Langley's machine made flights of half a mile, and three-quarters of a mile respectively, with no passenger. Maxim's machine was more ambitious. Surface area measured 4,000 sq. ft.; total weight, 8,000 lb.; the compound steam engine was of 363 HP., thus sustaining a weight of 28 lb. per HP., and the steam engine weighed less than 10 lb. per HP. It was intended to carry three men. Many experiments were carried out, the machine running on a railway of 8 ft. gauge. But one day it accidentally took flight and collapsed on reaching *terra firma*. Unfortunately, business interests have, up to the present, prevented Mr Maxim from carrying out further experiments. Other machines have been devised by Hargrave (Australia), Phillips (Great Britain), Tatin and Ader (France).

Up to the present, then, no practical flying machine has been invented. But success is born of failure, and as Lord Rayleigh says, "It is now only a question of time, and a lot of money." The two main problems awaiting a more perfect solution are—a satisfactory aerial motor, and the maintenance of equilibrium under all conditions. The motor car industry has helped towards the solution of the first difficulty, gasoline motors weighing as little as $12\frac{1}{2}$ lb. per HP. Maxim's steam engine, however, weighed but 10 lb. per HP. A locomotive weighs some 200 lb. per HP. A question bristling with difficulties, and entailing great personal danger in experiment, is that of preserving equilibrium during sudden gusts of wind. The necessary condition for this is that the centre of gravity of the machine and the centre of pressure of air shall be in the same vertical line. How to attain this provides a knotty problem for inventive minds.

Flying Shear. — A machine the invention of which was rendered necessary for the severance of billets in the **Continuous Mill**. It is capable of regulation to cut within a period of two hundredths of a second, and to sever billets within an inch of the

required length. The movement for cutting is adjusted by electrical contact controlling a trigger, which sets in motion steam or hydraulic cylinders, which in turn pull over a frame containing the lower shear blade. This frame is hinged to a bed plate, and the blade which the latter carries is a fixture. The upper blade is movable, partaking of the motion of a pair of links. These are pivoted to the main bottom frame below, and hinged to a cross-beam above, which is guided in a groove in the main upright frame. When therefore the main hinged upright is pulled forward by the controlling cylinder, the hinder inclined links, partaking of that movement, draw the upper shear blade downwards, cutting the advancing bar, and stops. The bar, still advancing, pushes the upper knife, and the hinged upright and links return to their original position until the next electric contact takes place. This machine was the invention of Mr V. E. Edwards of Worcester, Mass.

Fly Press, or **Screw Press.**—A hand-operated press (Fig. 36, Plate III.), employed for sheet-metal cutting, stamping, and drawing. A quick-pitched screw is rotated rapidly by turning a long weighted lever, so that a smart blow is struck, the dies being attached to a slide pushed down by the screw, and to the machine base. The frames are either open-sided, or enclosed, with two standards. The chief limitation of the press is that of speed, so that power-driven types oust it for much work, especially of the larger classes.

Flywheel.—The object of the flywheel is to equalise the varying pressures transmitted to the crank pin. When more pressure is being transmitted than is required to overcome resistance thereto, the wheel absorbs the excess, storing work. When the pressure transmitted is insufficient, then the wheel gives out work. In the first case it prevents acceleration, in the second it prevents retardation. It follows that the size of a flywheel is of little importance, the principal point is its mass and velocity; and for practical purposes it is sufficient to take the rim only, and neglect the arms. The diameter is generally three to four times that of the stroke of the engines. The velocity of the rim must not be so great as to overcome the tensile strength of the cast iron, say from 5,000 to 6,000 feet per minute.

The variation of speed permissible is usually from $\frac{1}{50}$th to $\frac{1}{80}$th from the mean velocity. The work in foot pounds stored in a flywheel rim equals $\frac{m \times (v)^2}{64 \cdot 4}$.

Where m = weight of rim in lb.

v = velocity of rim in feet per second.

The case of punching and shearing machines and some slotting machines afford examples of flywheels where the kinetic energy is used less for equalisation of speed than for supplying the *vis viva* necessary for the exercise of much power during a short period of time.

Flywheels are cast solidly, but with risks of shrinkage stresses fracturing the arms away from the rim. To avoid risk of this is the reason for casting wrought-iron arms into boss and rim. But these have often twisted off. Hence the largest and best wheels are built up. The rims are cast in segments, cottered, or bolted together, and the arms are cast singly, and bolted to the rims in various fashions.

Foam.—A scum cock is often termed a foam cock, a scum trough a foam collector. Priming and foaming are synonymous terms.

F.O.B.—Free on Board.

Follow Board.—A term applied to a bottom board on which a pattern is mounted.

Foot.—An extension measure equal in length to one-third of the standard yard. A flange or broad extension on which a structure is supported and by which its stability is ensured. A foot brake is one which is actuated by the pressure of the foot at the end of a lever—the foot lever. A foot drill and a foot lathe are each actuated by a treadle. A foot valve is the lower valve in a pump.

Foot Plate.—The plate on which the stoker and engine driver stand. It is a chequered plate of rolled steel with crossing ribbings, or cast with diamond chequers.

Foot Pounds.—A foot pound is a lb. weight lifted one foot high; or the pressure of one lb. exercised through a distance of one foot. It is equal to ·1382 kilogrammeter, a kilogrammeter is equal to 7·233 ft. lb., and these are the equations for the conversion of these units. A horse power equals 33,000 ft. lb. per minute.

A foot ton is a unit sometimes used in calculations of heavy hoisting machines.

Footstep Bearings, or **Step Bearings.**—Those, Fig. 37, which support the lower end of a vertical shaft. They are used for mill and turbine shafts. In some cases lateral adjustment of the bearing is necessary, which is accomplished with set-screws, or with bolts in slot holes in the pedestal. The principal difficulty with these bearings occurs when the weight of the shaft becomes excessive, hence the use of a tough brass disc or hardened steel disc to take the pressure of the shaft.

The subaqueous bearings for turbines are frequently lined with lignum-vitæ which is self-lubricating in water; but

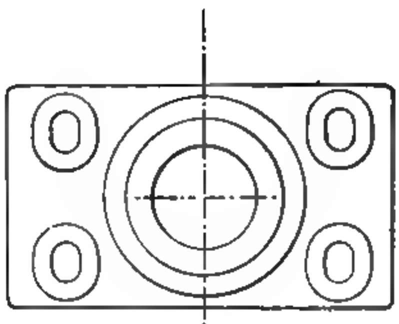


Fig. 37.—Footstep Bearing.

with the massive turbines now made oil is necessary, which is supplied from the engineers' platform. The details of construction also become complicated. Suspension bearings are often used in preference.

An example is shown in Fig. 38 for a Girard turbine, which lies below the bearing, the latter remaining above water. The fixed shaft A is supported in a step below the turbine. The shaft B, going up to ground level is driven from the sleeve C, which forms the actual turbine shaft. The pressure is taken on a step D, comprising a bell-metal mixture and hardened ring, within a cup which holds the lubricant.

F.O.R.—Free on Rail.

Force—Forces.—Ignorant of what force is *per se*, it is sufficient in engineering to define it as that which moves or tends to move a body. Any force or system of forces may moreover be graphically represented on paper; the forces acting on the balls of a centrifugal governor, in sheer legs, in a crane, in a roof truss may all be set down diagrammatically.

The (*a*) magnitude, (*b*) direction, and (*c*) point of application of a force must be known in order to represent it graphically. A scale is then adopted so that the magnitudes of the forces in tons or pounds may be represented by varying proportional lengths. In this way, the line AB in Fig. 39, 1, would represent a horizontal pull of 7 lb., and CD a push of 4 lb., at an angle of 30°. If two such forces (7 lb. and 4 lb.) be imagined to act at a point in a body, either as two pulls or two pushes, and if they be inclined to each other say at an angle of 60°, it is clear that the direction taken by the body will be neither in one direction nor the other, but somewhere between the two. If two boys walking on opposite sides of a road haul a barrow attached to ropes, its course will be along the middle of the road as long as they exert equal force. But if one pulls with greater vigour than the other the path of the barrow will incline more to that side of the road. Moreover when two forces thus act at an angle, a fraction of the sum of the forces is evidently lost, and we are left with the interesting problem, what direction will the body ultimately take, and with what amount of force will it be moved along that path?

Fig. 38.—Footstep Bearing.

This is solved by constructing what is known

as the parallelogram of forces. Lay off the two lines B and C (Fig. 39, 2), representing 7 lb. and 4 lb. respectively, inclined at an angle of 60°, the arrowheads showing the direction in which they act, in this case as pulls on the point A; if now the parallelogram be completed, and the diagonal R drawn, the line R will represent both the direction and magnitude of the force resulting from the action of forces B and C. It is deflected some 8° from the middle course towards the greater force, and, as regards its magnitude, it is only necessary to measure the length of R on the scale originally adopted. In this case it would be found to equal about 9½ lb. (9·6 exactly). R is called the *resultant* of B and C, and these two forces are the *components* of R; the process of finding the resultant is called the *composition of forces*. Another force E applied to the point A equal to R but opposite in direction would neutralise the combined effect of B and C, and hold the body at A in equilibrium. A third force such as this is called an *equilibrant* (Fig. 39, 3). Trautwine suggests the term "anti-resultant."

Certain truths are evident on reflection concerning this highly important principle (1), the resultant is always nearer the greater force; (2), as the angle between the forces increases, the resultant decreases; (3), the resultant is always less than the sum of the two components, though it may be greater than one of them; (4), if the components are equal and inclined at 120°, the resultant is equal to either of them.

Though the construction of the parallelogram of forces has the advantage of appealing to the eye, resultants may be found and with greater exactness by the use of mathematical formulæ. If the forces be represented by P and Q, the resultant by R, and the angle between them by a, the resultant, $R = \sqrt{P^2 + Q^2 + 2PQ\cos a}$. If, however, the angle of inclination is 90° $\cos a = 0$, and the formula becomes $R = \sqrt{P^2 + Q^2}$.

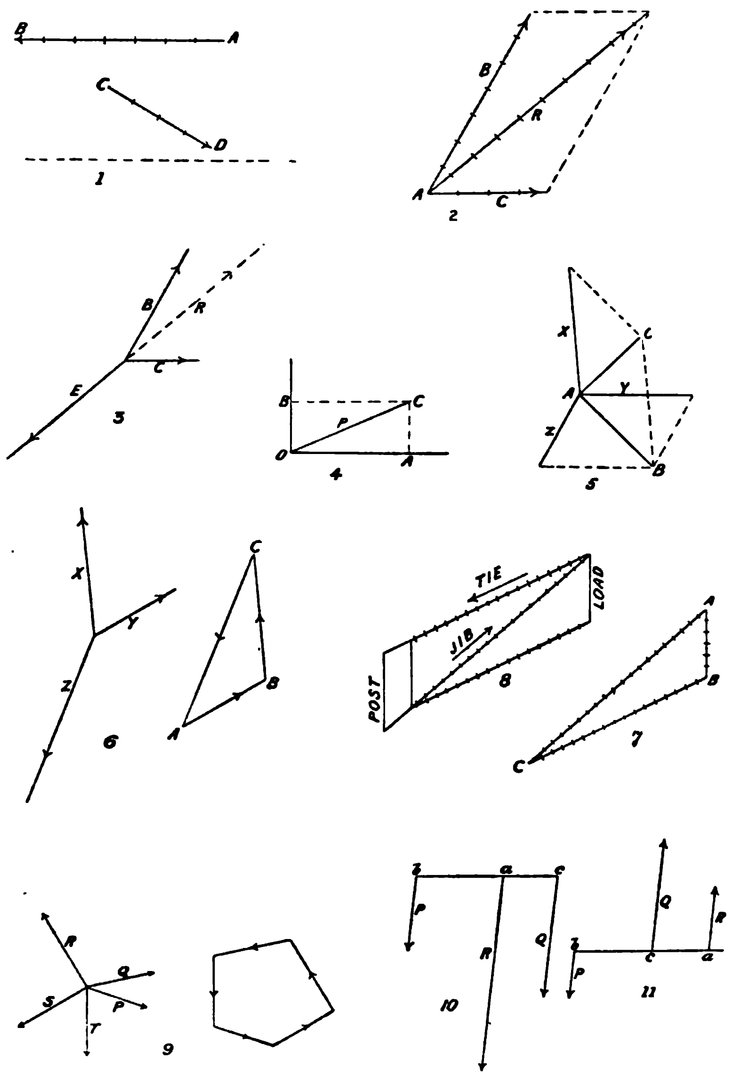


Fig. 39.—Forces.

The reverse process of finding a force resulting from the combined action of two others is that of resolving one force into two others which shall have an equivalent effect; this is called the *resolution of forces*, and amounts to constructing a parallelogram of which the diagonal is given.

Hence an infinite number of components may be drawn inclined at varying angles. If, as is generally the case, the components are to be at right angles, set off lines OA, OB, inclined at 90°, Fig. 39, 4; P represents the force for which components are to be substituted. From the extremity of P draw CA and CB parallel to BO and AO respectively. Then OA and OB are the required components.

The principle of the parallelogram of forces may be applied to the case of any number of forces acting at a point. In Fig. 39, 5, X, Y, and Z are three forces acting at A. By constructing parallelograms, AB is the resultant of Y and Z, and AC is the resultant of X and the previous resultant, AB; ∴ AC is the resultant of X, Y, and Z.

Two other laws of very great importance in engineering are those of (*a*) the triangle of forces, and (*b*) the polygon of forces. Strictly speaking, the first is a particular case of the second. The triangle of forces states that if three forces acting on a particle are in equilibrium they may be represented in magnitude and direction by the three sides of a triangle taken in order, and conversely, if three forces acting on a particle can be represented in magnitude and direction by the three sides of a triangle taken in order, these forces will be in equilibrium. Thus the three forces X, Y, Z, Fig. 39, 6, are represented by the triangle ABC:—

AB = Y, in magnitude and direction.
BC = X, in magnitude and direction.
CA = Z, in magnitude and direction.

In this manner it is possible to test the equilibrium of any three forces; if lines proportional to them produce a *closed* triangle, as in the above example, the forces are in equilibrium. The vast importance of this theorem is seen in particular in the construction of crane diagrams. The load on the crane, the thrust on the jib, and the tension in the tie-rod constitute three forces; the load being given, a triangle drawn to scale gives the other two factors. In Fig. 39, 7, the vertical line AB is drawn to scale to represent the load, say 6 tons, and from the extremities of this line AC and BC are drawn parallel to the jib and the tie-rod. The lengths of these lines measured from the scale, give the compressive load on the jib, and the tensile load on the tie-rod. Fig. 39, 8, shows the same calculation by the parallelogram of forces.

The polygon of forces is an extension of the triangle of forces, and states that if any number of forces acting on a particle can be represented in magnitude and direction by the sides of a closed polygon, those forces shall be in equilibrium. Given any number of forces such as P, Q, R, S, T, Fig. 39, 9, they are tested for equilibrium by arranging them in the form of a polygon as shown, care being taken that its sides are parallel to the direction of the forces and, of course, proportional to them in magnitude. If the polygon closes, the forces are in equilibrium. (If it does not, then a line drawn to close the polygon represents the resultant of the forces.)

The forces dealt with above are those which act at one point in a body. Those acting at different points and parallel to each other are called *parallel forces.* They may be *like* or *unlike* according as they act in the same or in opposite directions. It is self-evident that with two like parallel forces, as in Fig. 39, 10, (1) the resultant R will be equal to the sum of P and Q, and (2) R will act in the same direction as P and Q. The point *a* divides the line *bc* into two parts *ab*, *ac*, inversely proportional to the forces adjacent to them, that is, $ab : ac :: Q : P$, and ∴ $ab \times P = ac \times Q$.

But if the forces are unlike, Fig. 39, 11, then (1) the resultant equals the difference of the two forces, and (2) it acts in the direction of the greater of the two forces. The resultant will also act outside, instead of between the two, as in the case of like forces, but the point *a* is determined as before.

If two unlike parallel forces are equal, they can obviously have no resultant. Their effect is to produce rotation, and such a pair of forces is called *a couple.*

Force is also a term applied by sheet-metal workers to the upper die used in stamping.

Forced Draught.—The supply of the air necessary for combustion to boiler furnaces, under pressure above that of the atmosphere, by which combustion is intensified, and a correspondingly higher evaporative power obtained from a given grate area, and heating surface.

The idea on which the system of forced draught is based is this:—The air supply obtained from natural draught does not penetrate among the burning fuel and gases with sufficient velocity to produce perfect combustion; the presence of an excess of air is thereby rendered necessary in order to maintain the proper furnace temperature. But a large proportion of this excess is wasted. In forced draught, the air being driven with increased velocity, and in larger volume among the fuel and gases, becomes more intimately mixed therewith, and combustion is quickened and intensified. Although a much larger total volume of air is used than in natural draught, yet operating more effectually, a higher rate of combustion and higher economy are obtained per square foot of grate area, and consequently per square foot of heating surface, than with natural draught. In some systems the air is cold, in others it is heated first.

The successful application of forced draught dates from about the years 1882-3, at which period several engineers were working at the problem simultaneously. At about that period it was applied to H.M. ships *Satellite* and *Conqueror* in the navy; and to vessels in the mercantile marine by Mr Howden and Mr Fothergill. The first steamer fitted with Howden's system of forced draught in 1884, the *New York City*, a West Indian trader with compound engines, and 80 lb. steam pressure; developed from 17 to 18 I.H.P. from each square foot of grate area, with a coal consumption averaging 1·4 lb. per I.H.P. This was maintained for several years, the boilers being fed with salt water, except once in every three or four months when sailing from London; and remaining after over fifteen years of service practically as good as new. These results have been greatly exceeded since in other large ocean carrying steamers fitted with Howden's system.

There are cardinal differences in the systems of forced draught adopted. Omitting minor details in respect of fittings and pressures there are two main distinctions, the **Closed Stokehold**, and the **Closed Ashpit** system. In the first the air is forced into an air-tight stokehold. In the second it is forced into an air chamber attached to the front of the boiler. The warships of the Royal Navy, including torpedo boats, are fitted on the first system. The second system is that almost universally adopted in the mercantile marine. The closed stokehold system has many disadvantages by comparison with the closed ashpit system. There is no adequate ventilation for the stokers, and the results of hard steaming are invariably leaky tubes, and disabled boilers.

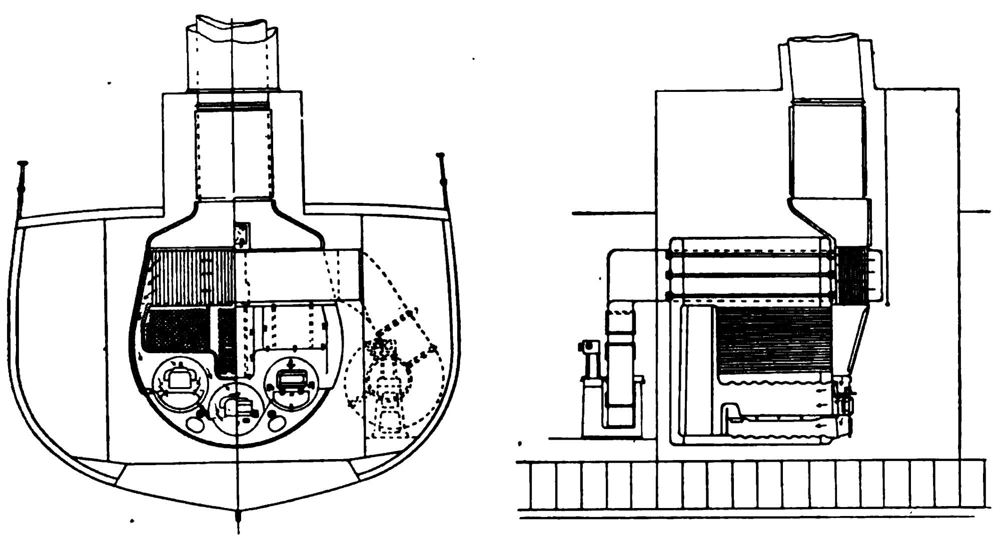


Fig. 40.—Forced Draught. Howden's System.

The principal details of Howden's system of forced draught are the following :—

The air for combustion is supplied by a fan (*see* Fig. 40) which discharges the air through a conduit into an air heating chamber above the smoke box, in which the air circulates round a series of tubes. The waste gases after leaving the boiler, and before entering the uptake, pass upwards through these tubes in the air-heating chamber, thus giving up part of their heat to the air, which then goes down passages at the sides of, or between the smoke boxes into an air-tight reservoir or chamber surrounding the furnaces. From this chamber the air is passed through the furnace fronts by valves into the ashpit, and over the fires through air-distributing boxes, in proportions exactly suited to the kind of fuel used, and the rate of combustion required, thus ensuring the most perfect combustion of fuel practicable.

The ashpits are separated from the furnace openings by means of dead plates extending between the boiler front and the outer plate of the casing. Separate valves are used for the admission of air above the dead plate into the furnaces, and below the dead plate into the ashpits, each being under perfect control. The furnace doors are double, the outer and inner ones being hinged in unison and moving together.

The air passes through holes perforated in the inner doors and also above them, and at their sides, and thence enters into cast-iron boxes within, whence it is diffused into the furnaces. The boxes also serve the purpose of protecting the inner plate and door from the intense heat of the furnace.

On the opening of a furnace or ashpit door for stoking, the air admission valves for that furnace are closed. No inrush of cold air can then occur. The air supply can be regulated by the admission valves for increasing or reducing the rates of combustion.

A good deal of experimenting has been done by Mr Howden in order to find out the most favourable methods and proportions of air admitted under forced draught, with their effects upon combustion and efficiency. Some of these experiments bore on the question of admitting the air both above and below the grate-bars. It was proved that there might be excess of air supply in both localities. It is necessary, or at least very desirable, that air should be introduced above the grate. In boilers worked under forced draught the plan of forcing air into the ashpit alone is not sufficiently effective. In the case of a thin fire being kept, the air blast will blow the fire full of holes, and the diffusion of combustion will be incomplete. In the case of a thick fire being kept, there will be an insufficiency of air above to combine with the gases, the supply will not be distributed regularly, and much smoke and carbonic acid will be formed. Besides this, though a minor matter, the fire-bars become burnt away rapidly.

The admission of air above the grate favours the formation of the higher oxide of carbon, with corresponding high liberation of heat units. It also burns up the coal-gas liberated during the coking of the coal. Further, it checks the too rapid inrush of the air through the fire-bars, and lessens their liability to become burnt out rapidly. But as the fires burn down, from the first throwing in of the fuel to clearness, the amount of air supply above the grates ought, as Mr Spence once pointed out, to be variable. And Mr Howden found that at certain times if the admission openings above the grates were decreased, and those below increased by the same amount, a much higher rate of combustion took place than when the process was reversed. The increase in rate of combustion does not, however, necessarily involve an increase in economy. Moreover, the intensity of the heat is so great when the pressure is entirely through the ashpit, that the fire-bars can be melted thereby.

In Mr Howden's system of forced draught, as much as 9½ to 10 lb. of water at 212° Fahr. can be evaporated from 1 lb. of Scotch coal, with a rate of combustion of 30 lb. per square foot of grate area per hour. The Navy Boiler Committee, when testing the machinery of the Cunard steamer *Saxonia*, found that the evaporation with ordinary Lancashire coal was 11·3 lb. of steam per hour, while the coal consumption per unit of power was 1·29 lb. per hour. As high as 50 lb. per square foot of grate surface has been burned per hour on boilers fitted with Howden's forced draught.

Some of the advantages of forced over natural draught are these :—More complete combustion, due to the more perfect diffusion and intermingling of the air, with the furnace gases. Higher evaporative duty from a given grate area, due to the larger quantity of fuel that can be burnt in a given time. Independence of weather and climate, a matter of value in calm weather. The greater rapidity with which the grate-bars can be cleaned, and the fires urged again into good condition. Inferior fuel can be utilised with forced draught. By means of the adjustable valves in the casings, the amount of draught and the rate of combustion can be regulated in any degrees within the range permitted by the fittings. By shutting off the draught, the furnaces can be kept still when the engines are not working. Or any single furnace can be shut off from the rest for a time. Another advantage is the reduction in size and number of boilers necessary to develop a given power. Or, with existing boilers, the advantage of immensely increasing their power, with a reduced consumption of fuel.

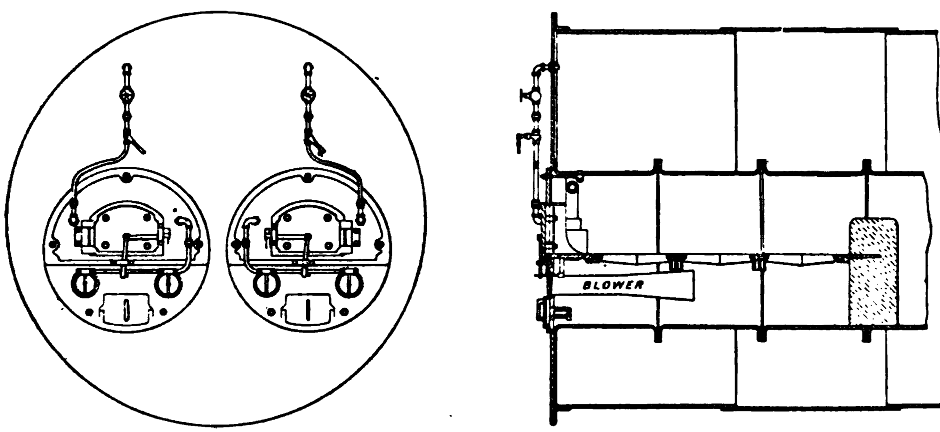


Fig. 41.—Forced Draught. Meldrum's System.

When the air is partially heated before entering the furnace, as in Howden's system, there is economy in the utilisation of a portion of the waste gases, and there is no risk of the furnace being cooled down by a rush of cold air.

When the front of the boiler only is encased with the air chamber, as in the Howden closed ashpit system, as distinguished from the closed stokehold system, there is no radiation of heat from the furnace front into the stokehold, and the latter is thus kept comparatively cool. There is no trouble with leaky tubes in the closed ashpit system, while the records of the closed stokehold system teem with the troubles due to leaking tubes. It is significant that no such trouble occurs with locomotives. The rate of combustion on the fire-grates of a locomotive is twice that on the fire-grate of a marine boiler, yet the locomotive tubes do not leak to any disastrous extent. Yet induced draught in the locomotive is used to a much higher pressure than the forced draught in any marine boiler. The difference between the use of forced draught in a marine, and induced draught in a locomotive boiler is this :—A very serious indraught of cold air occurs when cleaning the grate-bars in a marine boiler worked under the closed stokehold system. This is necessarily done while the engines are running, and the draught in full force. But in a locomotive this is done while the engine is at rest, and there is practically no influx of draught.

From the first application of the Howden system to steamships, it has been a remarkable and continuous success. At the present moment there are about 2,100 large sea-going steamers fitted with the Howden system, and the number is rapidly increasing every year. The aggregate I.H.P. of these installations is fully 6,750,000. They comprise steamers for almost all the principal steamship companies of the world. The two large new express Cunard turbine steamers,

Lusitania and *Mauretania*, have their boilers fitted with this apparatus, while amongst the famous steamers running with it are the *Carmania, Caronia, Empress of Britain, Empress of Ireland, Virginian, Victorian, La Provence, La Savoie, La Lorraine, Deutschland, Amerika, Kaiserin Auguste Victoria*, &c., &c. Some of these steamers have also been fitted with Messrs Howden & Co.'s patent oil-burning system, which is worked in conjunction with their coal-burning forced draught system. The results of this combination have been exceedingly favourable. Modifications of the Howden system for application to water-tube boilers have also been applied with great success to warships. It has also been applied on land, to boilers of all types, Lancashire, water tube, &c.

The Meldrum system of forced draught is applied as shown in the illustrations, Fig. 41.

The essential features of the system are the steam jet blowers introduced into the ashpit, and through which superheated steam is blown among the fuel. The furnace casing is made to fit close to the boiler front, and the ashpit is closed, forming an air supply chamber. The plate by which it is closed carries the blowers. It also has an air-tight door through which the fine ash is cleared that falls through the grate-bars. These, it should be mentioned, have only $\frac{1}{8}$-in. spaces to permit of the burning of inferior fuel.

The superheater is fixed just inside the furnace front over the dead plate. The steam pipe is brought to one side of the furnace front, and connected to the superheater, while the outlet of the superheater leaves on the opposite side, and is coupled to the feed bar that supplies the nozzle at the head of the blower. The steam supply is capable of regulation by a valve. The air is taken in at the blower head, and forced into the ashpit chamber under a pressure which is adjusted to suit the fuel and the duty required. This being equally diffused under the grate forces the air up through the fire-bars among the fuel. These blowers are made practically noiseless when desired.

Forced Lubrication.— The practice of supplying oil automatically to bearings under pressure by means of pumps and pipe arrangements. It is largely applied to high-speed engines, to turret lathes, and automatics. The necessity of supplying the lubricant under pressure instead of by gravity in engines, is, that gravity would not suffice to force the oil between bearings and shafts, between which there is considerable pressure. And in machine tools doing heavy cutting the pressure is necessary, in order to provide a full flow to convey the heat generated away, which could not be done by the action of a mere drip supplied by gravity.

It is hardly possible to overrate the importance of forced lubrication in modern practice. In engines it means noiseless working; economy and wonderful freedom from wear characterise the system. Enclosed engines used in electric lighting run continuously for many months without diminution in the supply of oil put into the crank chamber, and without sensible wear of journals and bearings. In the Belliss engines the pressure used is about 15 lb. per sq. in., and although the pressure on the bearings is greatly in excess of this, it has been pointed out that the relaxation of pressure on the return stroke in a double-acting engine permits the oil at these times to be driven between the bearing surfaces. Then during the fraction of a second occupied by the acting stroke, the film of oil cannot be squeezed out. In such a system, complete enclosure of the working parts is necessary, hence these are *enclosed engines*, otherwise the oil would splash out, and dirt get in.

In forced lubrication adopted in machine tools, the oil is bound to become dirty by contact with the metal being cut, and is therefore strained and filtered (*see* **Oil Filter**). The supply can be regulated by taps, and generally a spreader containing a row of openings distributes the oil along the work.

Force Fits.—*See* **Limits.**

Force Pump.—The essential feature of a force pump is the solid ram, substituted for the bucket valve of the suction pump. The force pump therefore does not depend for its efficiency on atmospheric pressure. The movements of the ram alternately create a vacuum into which the liquid enters through the suction valve, and force it out through a delivery valve. Liquids

can thus be forced to great heights, or against great steam and water pressures. The intermittent action of the pump is avoided by making such pumps double acting, as in the Worthington and others. Three-throw pumps are designed to provide a continuous supply, and the function of an air vessel is similar. The bucket and plunger pump provides a continuous stream. The force pumps used for high pressures are termed *test pumps* and *hydraulic force pumps*. In these the valves are small, and solid, and the metal in the body is very thick to sustain the pressure of several tons to the square inch.

Forces, Diagram of.—*See* **Force.**

Forces, Equilibrium of.—*See* **Force.**

Fore-Carriage. — The framework which carries the front wheels of a portable or fire-engine, or other bogie vehicle.

Foreman.—A man who has been promoted from the ranks of the workmen to take charge of one of the single departments in an engineer's factory. He is responsible for that department, but receives general instructions from the works' manager, or from the offices. He may be a working foreman in a small shop, but his duties of supervision in those of moderate and large dimensions absorb his entire attention, and often those of a deputy or sub-foreman also.

Forge.—The fire of the engine smith and the angle iron smith. Also the department in which work in malleable iron and steel is produced; the puddling mill with its equipment, the puddling rolls being the forge train or forge rolls. Forge scale is the flakes of black oxide of iron that form in quantity on iron forgings.

Forge Crane.—A type of crane used to convey forgings from the furnace or fire to the hammer, and to support them whilst being hammered. It is very similar in outline to a foundry crane, but is built in a more substantial manner in order to withstand the shocks it is liable to receive when suspending work under the hammer. It is very frequently an independent crane, *i.e.*, it has no top support, but depends for stability upon a central column and the masonry foundation. In place of a hook it is usually fitted with a chain sling arranged upon a pulley; the forging is carried in the bight of the sling, and is thus easily revolved under the hammer. In large cranes the sling pulley is revolved by means of a gear; electric cranes frequently have a small motor fitted for the purpose. Forge cranes are operated by hand, steam, hydraulic, and electric power; they are built in sizes from 4 to 50-ton capacity; above this weight it is usual to employ overhead travelling cranes.

Forge Pig.—The white grade of pig iron, also termed No. 4, used only for puddling for making malleable iron. An analysis of a Cleveland forge pig by Mr Ridsdale gives the following percentages. Graphitic carbon 2·72, combined carbon ·08, silicon 1·93, sulphur ·10, phosphorus 1·55, manganese ·75.

Forge Tests.—Tests of iron and steel performed at the forge or under the steam hammer, and so termed to distinguish them from those carried out in a testing machine. These last demonstrate the tensile, compressive, and torsional strengths of specimens, with reductions in area, very precisely. The forge tests reveal features which are not shown at the testing machine. The two may be distinct and separate, as when the forge tests are of such a character that they could not be carried out on an ordinary machine, or a special attachment to the same. Or they are adopted as tests of the behaviour of materials instead of machine testing. Or one may be supplementary to the other, as in tests for iron and steel for furnaces subject to intense heat, where the temper test is always insisted on in addition to the tensile and percentage elongation test.

Forge tests are performed hot and cold, the measure of a quality being the amount of extension or of bending that a specimen will endure without fracture. Thus, holes punched in a bar are drifted out hot to a diameter equal to that of the bar. In the ram's-horn test, a hole is punched near one end, and drifted to one and a quarter times the diameter of the iron, and a slit cut from the end to meet it, and the parts divided by the slit turned back upon the body of the iron.

Angle and other sections are bent back hot and cold until the webs are doubled upon one another, and also bent in the longitudinal direction.

Other forge tests concern plates, specimens of which are bent to certain angles varying with thickness. Another is to take a piece of bar and nick it and bend it to show the character of the fractured surface.

Forging.—The practice of producing parts in malleable metal or alloy as distinct from that of casting. The bulk of this work lies in wrought iron and mild steel, though it is practicable to forge some cast steel, copper, delta metal, aluminium alloys, and others.

The work of forging involves drawing down, upsetting, bending, welding, operations which are done on the anvil, with or without the extraneous aids of blocks of various kinds. The choice of methods as between drawing down and upsetting, or between these and welding, can only be determined on a consideration of the merits of each individual case.

Drawing down, or *swaging*, or *fullering*, is preferable to upsetting except in the case of short heats. Thus, in a long bar it is better if possible to upset a neck or collar, or to weld one on, than to draw down the long portion of the bar from a bar of the size of the neck or collar. But no large mass can be upset safely, because that operation opens the fibres. Upsetting is often an essential preliminary to bending, because of the extension of the fibres with reduction of cross section that occurs in the latter. Welding is not desirable when it can be avoided in vital sections. But there are hundreds of sound welds made for one faulty one, and an imperfect weld can generally be detected by inspection. There are several precautions essential which will be found treated under **Welding**.

The formation of holes is done by punching, and drifting, or by bending round an eye and welding it. In punching, as in swaging, the point to note is that sharp severance of fibres must be avoided.

Forging is essentially a moulding process, which explains why swages and fullering tools never have sharp edges. This, however, is more important in wrought iron than in mild steel. In the former the direction of grain or fibre must be considered, in the latter it is not appreciably present. The strength of an iron forging may be lessened by 4 or 5 per cent. by placing the short fibre in the direction of greatest stress.

The province of forging has been invaded in two ways. In one by the growing use of die forgings, in the other by the increased employment of mild steel. Die forging has taken much of the small and repetitive work of the smith. Mild steel ingots have appropriated most of the heavy work formerly fagoted and done under steam hammers, with much welding, upsetting, and drawing down. The steel is more homogeneous, and weldless forgings can be produced that were impossible with iron. Steel castings also have taken the place of intricate forgings both light and heavy. The finest examples of these perhaps are the stern frames of vessels.

Forging Dies.—Die forging is the practice of producing forgings in quantity in matrices termed dies, or stamps. It is accomplished under drop hammers, steam hammers, in presses operated by steam, and hydraulically. It is suitable for small forgings, and for those of medium dimensions, but not for the most massive. It scores most economically when large quantities of small forgings are required, but it is adaptable also to the production of lesser quantities, and also to the bending of work from plate, when uniformity in dimensions is essential.

Die forging offers three practical aspects. It may be a finishing operation only, Fig. 42, A, following preliminary work done on the anvil. This is often practised in smithies where the numbers of similar forgings are not large. Preliminary upsetting, drawing down, and rough forging is done on the anvil, and the dies are used simply to complete and neatly finish the forgings to exact dimensions. Or die forging may be preliminary to work completed at the anvil; or each may take a share of the work alternately, as in the operations of swaging, bending, punching, welding, and cutting off, in both of which the advantages of the power hammer and suitable blocks are great in medium heavy work.

In die forging absolute there is no anvil work at all, but the stampings are produced from bar wholly. Here results are obtained that would seem almost impossible apart from experience. Shapes the most awkward are

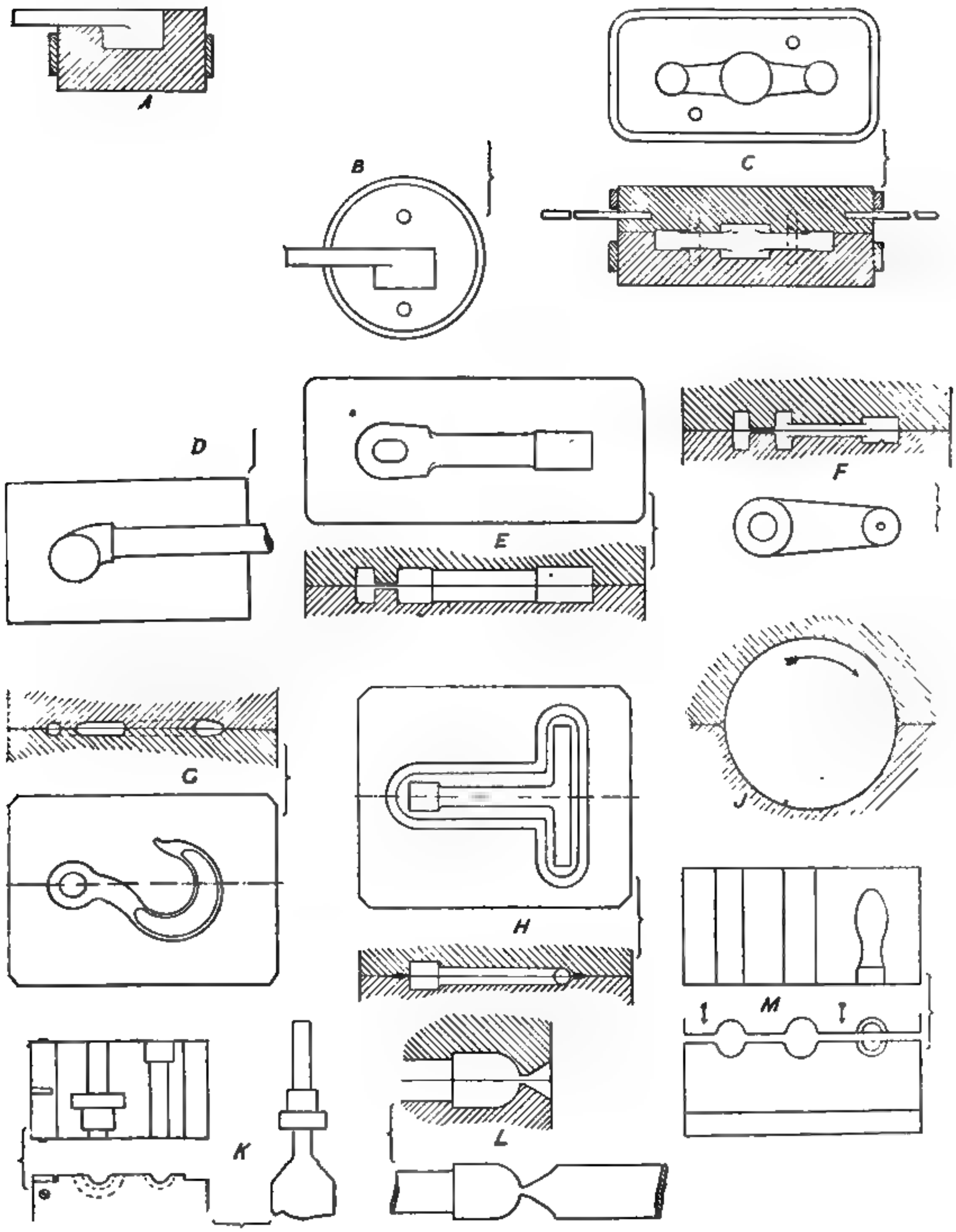


Fig. 42.—Forging Dies.

produced, often involving the employment of two or three dies in rapid succession. Often in small work two or three separate pieces are produced at one heat. Such results are only possible by rapid working on material raised to a welding heat. Upsetting is not done to any extent in this class of work, but reduction mostly. The hammer blows are rapid.

One of the difficulties inseparable from forging in dies is the formation of fin, or flash. This is prevented in work of circular section by turning it about in the dies between each blow, or few blows, so obliterating the fin. In other shapes the fin is cut off in separate open dies, termed *stripping dies*, under the hammer, or in a trimming press. Often where the amount is not large, it is left to be cut or ground off when cold.

The formation of scale is avoided by dashing a little water, or oil and water, on the forging as the work proceeds.

The expense of dies is a relative matter. For small numbers of pieces cast iron is the material commonly used for dies, being cheaply and readily produced from patterns. Bonding is then generally necessary. Small stamps made in large quantities are almost invariably of mild steel, the shapes being cut out by hand, or by the aid of machines. These are fastened to the anvil, and the tup; while the cast-iron dies are generally simply laid in place, and the tup strikes the blows down on them.

A great advantage of die forging is that allowances for tooling can be reduced. In a forging made by hand, excessive allowances often result in some parts, with increased cost for tooling. When forgings have the minimum allowance regularly distributed they can be fixed in jigs, and thus further economy results. In some classes of work machining may be dispensed with in favour of a black fit. Or grinding can be cheaply substituted for machining by cutting tools. The practice also tends to standardisation of pieces. When die forging becomes a regular system, the work of the trained smith lessens, just as that of the moulder does when machine moulding is adopted. This is in harmony with the industrial trend of the present time.

In the sheet of illustrations which give examples of die forging, Fig. 42, A, is a cast-iron bossing die bonded with wrought iron. The flat hammer tup serves instead of a top die. B is a similar article forged between top and bottom dies, but turned quarter round. C is a pair of dies dowelled and having handles in the top portion. These are simply laid upon the anvil and struck by the tup. D is a pair of dies attached with dovetails to the anvil and tup. E and F illustrate the punching of holes with punches embodied in the dies; and alternatively to driving an independent punch through the forging. G is a hook, generally roughly prepared by bending around a mandrel or the anvil beak, and finished neatly in the dies. H shows a device for receiving the fin from forgings, consisting of a groove adjacent to the edges. J illustrates the rounded edges adopted in circular dies to receive the small amount of fin produced at a single blow. K shows the dies used for making the forging seen to the right. L is a die and its forging, the surplus fin being pushed out at the end. M shows the dies for a handle.

Die Making.—Dies are cast, cut or sunk, or hubbed. We consider each in turn.

Cast Dies.—These are made in iron or steel from patterns, Fig. 42, A, B, C. As dies must needs have draft on their perpendicular edges, this harmonises with the draft or taper required for moulding, so that a pattern made to deliver from the sand will have the necessary draft for the free delivery of the forging. It is often advisable to core the forging space rather than to let it deliver, because a cleaner, more accurate recess may often be thus produced. In this case a print and core box will be required just as in other ordinary work. As a general rule, shallow recesses of concave section may be made to deliver, but deep ones with nearly perpendicular sides are better cored out. But often by making the pattern in two portions, separated loosely along the plane of the bottom of the recess, coring may be avoided, because the portion containing the recess can be put back into the mould, and nailed, and made good.

Not only must the usual shrinkage allowance be given to the pattern for the casting itself, but another allowance for the shrinkage of the forging. This last will equal $\frac{1}{8}$ inch to the foot for wrought iron, and $\frac{3}{16}$ inch for steel. Besides

these, there must often be recesses cut around, or at one or both ends for fins.

Cast iron, being rather brittle, is not the best material for dies, hence it is necessary either to make the metal excessively heavy, or to bond the dies with rings of wrought iron or steel. The latter method is preferable, Fig. 42, A, B, C. The bonds may measure $1\frac{1}{2}$ in. × $\frac{3}{4}$ in. in cross section, and they should be shrunk on. As these dies are heavy, the question of handling them arises. If of medium size, say not exceeding about 6 inches diameter, they can be lifted with hoop tongs, but over that size they ought to have handles of wrought iron cast in to lift them by, Fig. 42, C. The reason is that these heavy dies are seldom attached to the tup as the smaller forged ones are, but are simply laid on the bottom die, and struck with the hammer. These handles may be from 2 ft. to 3 ft. long, cast in, and dropped into print impressions.

Cast dies are smoothed up a little with the file, but as a rule they are not tooled in machines to any great extent. Holes may be drilled, and boss recesses bored, or plain edges planed or milled, but generally they are used nearly as cast.

Cut Dies.—In the heaviest class of work there is no choice, since cast iron and steel alone can be used for the materials of dies. But they would be wholly useless in small forgings, made in large quantities, first, because they have to be tooled carefully, second, because they would fracture. Nearly all small dies, and many of fair dimensions, are therefore made by recessing solid blocks of mild steel, or temper steel, to be subsequently hardened. Here there is a wide scope for different methods. In the engineer's shop the methods are those common to the machine shop. In the shops where drop forgings are made, the use of former guides to the cutting tools is common, and machines are built or modified for die sinking.

In intricate work done by any method, a good deal of cutting has to be done by chisels, drifts, and files, following after, or independently of machine operations. The machines used for cutting dies are the lathe, drilling machine, slotting machines, and slot drills, shapers, and milling machines. All these do good service, but the chief perhaps are the slotters and millers. When dies are slotted it is necessary either to tilt the table to obtain the draft angle, or the slotting arm is made capable of adjustment for angle. When several dies all alike are required, a former die is used, from which the other dies are cut, using when necessary a profiling milling machine.

In nearly all cases it is desirable or necessary to have a templet or dummy of the shape of the forging to be made in the dies, with any allowance necessary for shrinkage. This is either of the shape of the forging, or it is a temporary piece formed by squeezing a mass of lead in the dies, while in progress of formation. The dimensions being then measured, indicate how the work is proceeding, and from what parts material has to be removed.

Hubbing.—The hubbing or typing method of die formation is not used much. It is an old method suitable for stamping shallow patterns, but not of much value for deep work. It is employed still for some very intricate patterns, and for some patterns of circular section, and it is a finishing operation sometimes used. The pattern to be typed is prepared, attached to the end of a porter bar. The dies are raised to a white heat, and hammered around the pattern, which is thus pressed into them. If the section is circular, it is rotated constantly. In such a section it is not necessary to plane the joint faces subsequently because the convexity of the edges left by the sinking in of the pattern piece or print is favourable to the suppression of fin in the work of forging. But for shapes that cannot be rotated, the dies are planed subsequently on the face and edges to close the joints, and to remove the irregularities caused by the squeezing out of the metal.

Forging Machine.—For the rapid production of work having comparatively small diameters, combined with considerable length, the swaging type of forging machine is employed, in which a row of dies faces the operator, and enables him to gradually reduce and shape the ends or bodies of work by a great number of blows, as distinct from very few imparted in ordinary die forging. Bolts, studs, pins, rollers, drills, shuttle tips, rail heads, &c., are a few of the many articles made thus. The Ryder machine,

Figs. 43, 44, 45, carries at the top of the frame an eccentric shaft A, driven by fast and loose pulleys B, and having heavy flywheels C, C. Shaft A runs in bushed bearings, the bushes at the two ends being split and adjusted with a cotter device, as seen to the left of Fig. 43. In the space between each bearing the eccentric portion imparts motion to a block D (one only being shown in Fig. 43 and Fig. 44), pressing down a ram or slide, into which the top die is fastened. This slide is kept up to the piece D by the spiral spring seen in Fig. 44, a cotter having its end let into the machine framing serving to keep the spring in compression. The guides for the ram are of square shape, as seen in the plan view above Fig. 44. The bottom die holders E also fit in square bearings. The fitting at F is for raising one die as forging proceeds, so that a considerable diameter reduction may be effected without the use of three or four differently sized swages. Another method of raising is shown at G, wedges being actuated by screws, giving a more solid bearing underneath than the screw device at F. The brackets at H are adjustable, so that the work may be supported in line with the dies, and they also form stops for length, when repetition work is done.

In Fig. 45 a special treadle-gear device is illustrated, the object of which is to rapidly raise or lower the bottom die to a considerable extent, as is necessary when forging collars on shafts, a good drop being required to get the work between the dies. The treadle is connected to a wedge piece G by levers as seen, a stop screw behind limiting the amount of lowering. A weight (not shown) on the tail of the treadle lever, keeps the latter raised up when released. Fig. 46, Plate III., illustrates a similar class of machine, with the dies in position.

Forging Press.—This owes its development to the enormous growth in the dimensions of steel ingots. The steam hammer was soon found to be inadequate to the task of working thick masses, besides which the vibration of big hammers is objectionable. Figs. 47-50, Plate III., illustrate forging presses of approved types.

The effect of a hammer blow is not felt at the centre of a massive ingot. The latter resists the blows, and though the surface is extended, the interior is scarcely affected. With a press, the opposite conditions are established; the central portions being the hotter, are made to flow and spread more than the exterior. So important is this difference, that the Bethlehem Steel Works in America discarded a new 125-ton hammer, erected at a cost of £40,000, and installed a press in its place at a cost of £96,000.

Many difficulties arise in the construction of the heaviest forging presses, in which total pressures of from 4,000 to 14,000 tons have to be exerted. The press cylinders have to be of cast steel or forged steel, and the pumps have to be bored in forgings of solid steel. The pressure on the valves is concentrated on the small area of the seatings, and the slightest leakage becomes enlarged by the rush of the water. The conditions in the smaller presses used for ordinary forging are different.

In forging presses the pressing ram and its cylinder are above the work. The anvil, and tup, or "pallets," are carried, one on the base casting, the other on a pressing head at the end of the ram. The head generally in large presses slides on, and is guided at the corners by four columns, attached to both base and entablature or crosshead, with the ram cylinder supporting the latter. This sliding head is an important detail, its bearing on the columns taking side thrust, which comes on when the forging is out of centre. Side thrust is liable to occur in flat forgings, but not with circular work on vee blocks. A better design to withstand side thrust is the double ram (duplex cylinder press) having a central guide in the crosshead. Both base and entablature in heavy presses are built up, both for facility in erection and to avoid heavy single masses.

Presses are variously driven. An existing pressure service may be used, but the heaviest presses have their own set of pumping engines running continuously, with an accumulator by which the head is lifted through the medium of small lifting cylinders. The ram is lowered through what is termed the "clearance part" of its stroke, that is, before it comes into contact with the forging, by exhausting the lifting cylinders; and the main cylinder is kept charged from a low pressure reservoir. The actual

PLATE III.

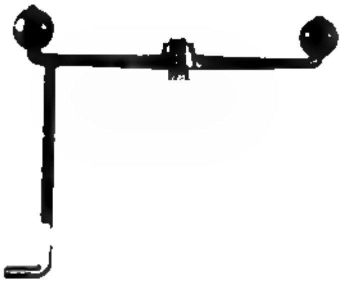


Fig. 36.—Fly Press, with Single Standard.

Fig. 46.—Forging Machine.

Fig. 47.—Davy 1,200-Ton Rapid Action Forging Press, with Steam Intensifier (Cylinder below ground line).

Fig. 48.—3,000-Ton Davy Press, Duplex Cylinders, and Hydraulic Mandrel and Tool-changing Gear.

Fig. 49.—150-Ton Davy Rapid Action Forging Press, with Steam Intensifier.

Fig. 50.—Armour Plate Forging Press.
(Sir W. G. Armstrong, Whitworth, & Co., Ltd.)

To face page 46.

Fig. 43.

Fig. 44.
Forging Machine. (Thos. Ryder & Son.)

Fig. 45.

squeezing is then effected by means of increased pressure produced by a steam intensifier in which the steam cylinder is large and actuates a small hydraulic ram. The valve is actuated automatically in the best machines when the forging is touched by the ram. There is much interesting variation in details of the designs of different makers.

In some designs the accumulator is omitted, and the pressure is effected directly from the pumping engines, which are stopped and started as required.

The number of strokes per minute in forging presses varies from 20 or 30 in the largest to 60 or 80 in the smaller and medium presses, designed to take the place of the hammers in the smithy. Rapidity of action is necessary here; and having this, there is the added advantage of more precise work, and the fact that deep foundations are unnecessary, that less steam is required, and fractures less frequent.

Mr A. T. Capron gives the following data for the power of presses required for working on ingots of different sizes:—

Power of press. Tons.	Maximum diameter of ingots. Inches.
300	10
500	14
800	20
1,200	27
1,500	36
2,000	48
3,000	60
4,000	72

For engineers' small forgings, such as can be made out of blooms 8 inches square, or flats 12 in. × 6 in., a 300-ton press is suitable; while for the largest marine forgings for shafts and cranks, a 3,000-ton press is usually sufficient, being capable of dealing with 60-in. ingots. The most powerful presses, from 8,000 tons to 14,000 tons, are required for armour plates and gun forgings.

Forked Chuck, or **Forked Centre,** or **Pronged Chuck.**—A chuck, Fig. 51, used for turning wood between the centres of a lathe. It usually screws into or over the mandrel nose. It is tapered to a thin edge with a projecting centre, and generally two prongs projecting not quite so far as the centre, thus forming a sort of fork which is forced into the end grain of the piece of wood, compelling it to revolve with the chuck.

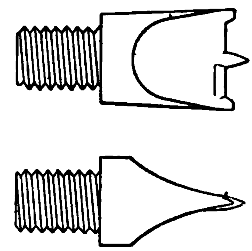


Fig. 51.—Forked Chuck.

In hardwood a sawcut is generally made for the fork to enter. The wood may be forced on to the fork by the screw of the poppet, or in some cases this may be assisted by first driving the wood on by a few taps with a hammer.

Forked Ends.—An end is forked when in addition to forming a bearing for a spindle it has to provide clearance space for the movement of the end of the object it embraces. It may be a plain end with bored holes only, or fitted

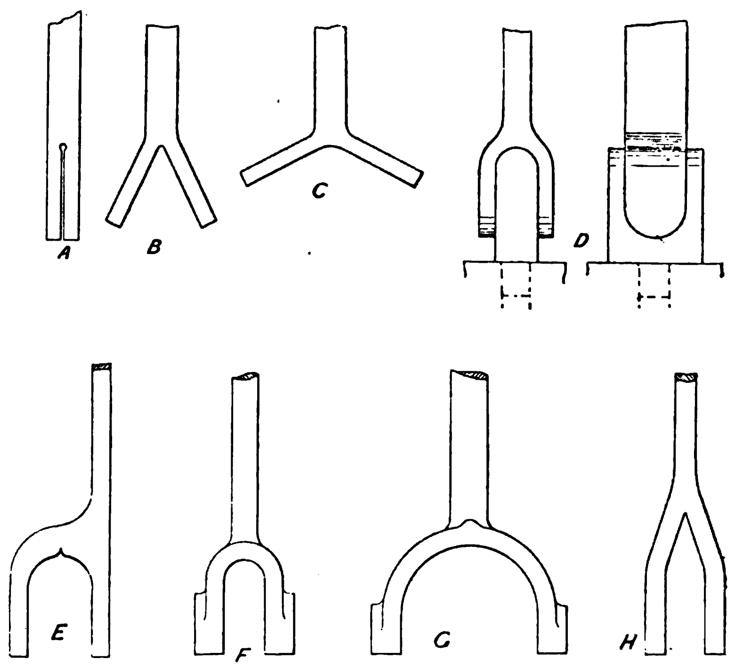


Fig. 52.—Forked Ends.

with brasses, caps, or cotters. *See* **Connecting Rod** for examples.

The forks are either made by bending, or the end is forged solidly, and the space slotted. The first is done in the larger forks, the second in the smaller. Bending is, however, more necessary in forks of iron than in those of steel because of the fibre present in iron. Stamping in dies is either a finishing operation, or ends are produced wholly in dies.

Fig. 52 illustrates the stages in the opening out of a forked end from the bar. It is first divided, A, with the hot sett cutting from opposite faces, then spread and opened out, B and C. Afterwards it is bent to shape by hammering it over a form, D, inserted in the hole in the anvil. The slitting and opening have to be done carefully in iron for fear lest the fibre should be opened out beyond the fork, as in the illustration, E. It is therefore usual to punch a hole before slitting, A, which prevents the metal opening beyond the hole, and leaves a small radius there.

When bosses are formed on the ends, F, G, these must be made while the ends are spread out like C, or more widely. This is a tedious job, because fullering and shaping have to be done, and on both forks alike. In such work the advantage of using dies if only for finishing is great, because the ends can be brought roughly to dimensions, and then finished at a final heat in the dies. The jointing of the dies is in the plane of the paper. In the case of forked ends like H the cutting and opening out are necessary, and the form inserted is of the same shape as the internal portion of the fork.

Form Cutters, Form Milling.—A method of milling by the use of cutters shaped to the profile of the work. It will be found treated under **Profile Milling.**

Forming Tools.—In repetition turning, great economies are effected by the employment of forming tools. The principle is simple—that of making the tool edge to the same outline as that of the work to be turned. The value of the system lies chiefly in curved shapes, and in combinations of curves and straight parts, which would be tedious and costly to repeat by ordinary turning methods. Forming is therefore applied to cocks, and fittings of all

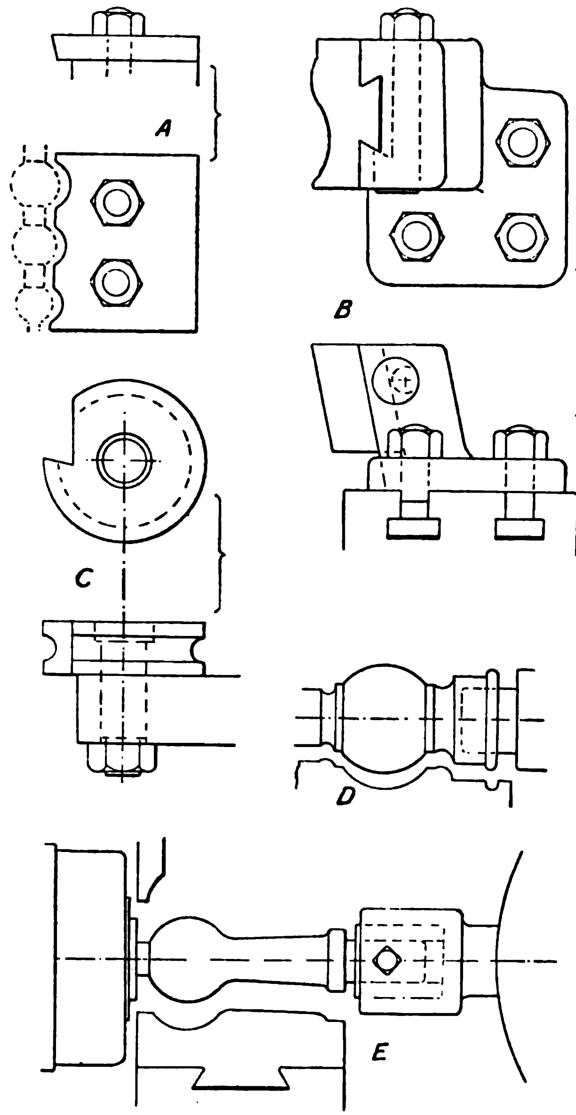


Fig. 53.—Forming Tools.

kinds, handles, knobs, special pins and screws, hubs, &c.

The flat type of forming tool, Fig. 53, A, has the disadvantage that re-grinding soon reduces the thickness so much as to render the tool weak. A better style is that shown in B, the

tool being a deep strip held vertically in a block by means of the vee, and a bolt. The whole front of the tool is milled down to the required profile, and grinding is done on the top face, so that the piece of steel lasts for a very long time.

The circular forming tool, C, is produced by turning the body to the profile, and then slotting out a space to form a cutting edge. Re-grinding is done on this edge, but the tool cannot loose its profile. This method of making is more suitable for small tools than large, if only on account of the quantity of steel used up by comparison with a flat tool.

The strain on a piece of work while being formed is very severe, and it must be well supported; holding at one end, in the chuck alone, being insufficient except for very short pieces. In turret work a "steady bush" or a "steady pin" is employed, to support the outer end, as in Fig. 53, D and E. Copious lubrication is essential to good work in forming, because of length of cut involved, and the fact that the tool is fed straight in, without the help afforded by an endlong travel, as in ordinary turning.

Forming is done in turret lathes, automatic screw machines, and also in special forming machines, which do only forming and cutting off. In all cases a cross-slide carries the tool transversely to the spindle axis, and the cutting-off tool is mounted opposite, E. A hand lever feed is given, or an automatic one, according to the class of machine.

Foucault Currents.—Eddy currents induced in the iron core of an electro-magnet. *See* **Eddy Currents** and **Dynamo.**

Foundation Bolts.—Long bolts used for securing cast or plated foundations to the ground prepared for them, as concrete or masonry. As the bolt heads cannot be reached after they have been covered in, the heads have square necks fitting in washer plates or cottered ends to resist the turning action of the nuts above. As the bolts have to be inserted before the materials are filled in, or built in, they are inserted by a templet, the centres in which correspond with the centres of the holes in the work above ground level.

Foundation Cylinders.—Cylinders of cast iron sunk in the beds of streams and in dry soil on which to erect the piers and abutments of bridges and viaducts, and bolted one above another by internal flanges. Cylinders of concrete also serve the same purpose; in some cases they are aggregated over an area to give broad foundations. Some cranes have their foundations on a cylinder of cast iron, or plated work filled with concrete.

Foundations.—Piling, though not practised to the same extent as it was fifty or a hundred years ago, is still of great value when deep foundations have to be laid in mud, sand, and silt; and in countries like the United States and Canada where timber is plentiful, and more readily obtained and transported than iron. One example of this kind is that of a bridge, 2,484 ft. in length, at the city of Alton, near the confluence of the Mississippi and Missouri, founded wholly on timber. Piles driven down into the river bed are cut off 10 ft. below low water, and on these a timber staging, 60 ft. by 20 ft. wide, is fastened, built of crossing timbers 12 in. square, making a depth of 5 ft. above the piles. On these the masonry piers, 40 ft. high, are built.

But there are some rivers in which the current is so swift, and the bed so yielding, or full of quicksands, that no piling would be secure. Then a solid mass of masonry has to be built in the depths. The work is done in a coffer dam, or a caisson built in the stream.

Much greater difficulties are often experienced in laying foundations in some foreign countries than those which engineers have to face in the small streams and estuaries of Britain. Some of the rivers in the United States and Canada have given great trouble to bridge builders. The superstructure is often a mere trifle by comparison with the foundations. Huge masses of ice come crashing down the rivers in Eastern Canada, the St Lawrence, the Ottawa, the St Maurice, and others in winter time, hurling with terrific force against piers and abutments. The timber rafts, too, of the lumbermen sometimes get broken away, and swept down against the piers by floods. Mighty torrents, swollen by the melting of the snows in spring, are of greater magnitude than are met with in our own country.

Difficulties of another kind occur in the

Mississippi, Missouri, and streams of that class which readers of Mark Twain's "Life on the Mississippi" will be prepared to appreciate. When a stream runs an even regular course, even though it may be wild at times, it offers no special difficulties. But what can be done with an erratic shifting river that changes its ways several times in the course of a year? To-day it will be running down in a well-defined channel, a month or two hence it will have gone off at a tangent and made for itself another passage. When that is liable to happen then *training works* are necessary. A *mattrass* is a dyke laid to coerce or train a river to pursue a properly regulated course instead of an erratic one. To mention one instance only, that of a bridge at Nebraska city. The Missouri had changed its course, taking to a narrower branch, and the engineer in charge trained the river in a way which would lessen the length of the bridge the construction of which they were contemplating. A mattrass of woven willows was made, 125 ft. in width, with a selvage of wire, loaded with stone, and sunk. As it sunk, more stones were piled on until it went down into the mud and sand below the reach of the scour of the river, and formed the foundation for the dyke which now prevents the stream from returning to its old course. This bit of mattrass work cost £11,000, for it swallowed up 4,236 cords of brushwood, 18,405 tons of rock, and 7,438 lb. of wire.

The most erratic rivers in the world are those in the Indian Punjaub, which will on the occasion of great floods sometimes wander away miles from their original course, changing their channels in a few months. The Chenab River is one of this class, and Mr Bell, before constructing the Sher Shah bridge across it, reduced the stream from about 8,000 ft. in width to 3,600 ft. by means of artificial banks, or training walls. These banks cost about two-fifths of the total expense of the bridge. Yet this expense, by shortening the bridge, was true economy; because, but for that the structure would have cost about £100,000 more than it actually did.

One of the largest aqueducts in the world spans the river Kali Naddi in one of the north-west provinces of India. This was built to take the place of one which had been washed away in 1885. It was an insignificant stream, only 50 ft. wide at ordinary times. But a great rainfall, equal in some places to 15 inches in twelve hours, came, and a fierce flood swept down the valley until the waters spread out into a torrent a mile wide in places, and piled like a wall 14 ft. higher on the upper side of the bridge than on the lower. Then the foundations were swept away, and the aqueduct was carried down by the torrent. The engineers then built another, but sunk the foundations this time 55 ft. below the river bed. These were formed of circular cylinders, built of brick. The river bed was excavated within and below the brick cylinders, or "wells"; the latter were filled up with concrete, and upon these the bridge was built.

In the case of a bridge over the St Maurice River in Canada, openings were cut in ice 2 ft. thick, and piles 50 ft. long were driven down into the clay bed beneath. Between these the gravel was dredged out, and other longer piles driven, and sawn off level with the bottom of the river. Divers afterwards went down and packed stones between the heads of the piles; upon the heads solid layers of timber 4 in. square were laid, and over these in the summer time a caisson was floated into position, and the masonry was built within it. The Blair Bridge over the Missouri, 1,000 ft. long, is carried on four piers, and two shore end foundations; the cost was £44,000 for foundations alone.

The average cost of each pier underneath the present Tay Bridge was £4,000. This includes the masonry that rises above the water, but the buried work hidden in the foundations amounted to nearly £2,000 for each pier.

Every one knows the story of Chat Moss, but more remarkable is the fact that wool has been used as a foundation for bridges in quicksands when other methods have failed.

When the National Pike Bridge, west of Richmond, U.S.A., was being constructed, a quicksand was reached, apparently bottomless. The order was given to buy up all the wool available in the country round. Enormous quantities were swallowed up by the quicksand, and it was pressed down until at last it would

sink no farther, and on that the foundations were built.

Many harbour walls and piers are now built on sacks or bags of concrete. These bags lie close to one another, and accommodate themselves to the rocks on which they lie, and harden; they receive the concrete blocks above, and their contents harden into solid rock. *See* **Bag Work.**

In one particular length of 4 miles of the New York Elevated Railway, extending from Eighty-Third Street to the Haarlem River, the amount of foundation is enormous. In parts adjacent to each other a foundation would have to be blasted 10 ft. or 12 ft. down into solid rock, and in the next a few feet away it had to be taken down through 30 ft. of quicksand. In this 4 miles of track there lie buried $11\frac{1}{2}$ millions of bricks, 32,000 barrels of cement, 1,815 piles, 947,000 ft. of timber, 9,000 cubic yards of concrete; 95,000 cubic yards of material were excavated, 6,400 of which consisted of solid rock.

The Ganges at Benares is spanned by a railway bridge that was built under very awkward conditions. In the dry season, the flow of the river does not exceed a mile an hour, during rains it will sometimes course along at 15 miles an hour, and the river bed is then scoured to a depth of 70 ft. below low water, or 120 ft. below flood level.

The Charing Cross Bridge is carried on iron cylinders 4 ft. in diameter, and if the bridge were fully loaded with engines the pressure would be 8 tons on each square foot.

The importance of deep foundations may be estimated from the fact that although the fall of the old Tay Bridge was not due to any failure of the foundations, yet when the new bridge was built, new foundations were laid, going down 20 ft. into the bed of the estuary, or about twice the distance of the old ones. The value of the foundations at the new Tay Bridge, which does not include the masonry piers that come out from the water, is £31,600.

Among the deepest bridge foundations in the world are those under one that spans the Hawkesbury River in New South Wales. Here the bottoms of the piers range from 151 ft. to 215 ft. below the rails. These were built in caissons of iron. *See also* **Bag Work, Block Work, Caisson, Concrete, Monolithic Work, Piles.**

SAFE BEARING STRENGTH FOR BEARING BLOCKS OR FOUNDATIONS.

(Redpath, Brown, & Co., Ltd.)

	Tons per sq. ft.
Granite blocks - - - - - -	40 to 60
Limestone blocks - - - - -	15 „ 25
Sandstone blocks - - - - -	20 „ 35
Ordinary brick, in lime mortar -	2 „ 3
Hard brick, in cement mortar - -	5 „ 8
Portland cement concrete, six months old - - - - - - -	4 „ 6
Compact gravel or sand not free to escape - - - - - -	2 „ 4
Compact earth or dry clay - -	1 „ 2
Rock foundations $\frac{1}{8}$ to $\frac{1}{10}$ the crushing strength.	

Foundations for Cranes.—The stability of a fixed crane depends on its foundation. With ordinary conditions of soil it is a comparatively easy matter to provide a sufficient mass of concrete or masonry to ensure stability. When a crane is fixed on board ship or upon a timber or steel-framed pier, it is necessary to arrange special stiffening beams to carry the forces to the main members of the structure.

A typical concrete foundation for a hand crane is shown in Fig. 54; the load is 5 tons at 18 ft. radius, the main bedplate is provided with six bolts, $1\frac{5}{8}$ in. diameter, which pass through the concrete and are held with cotters under a bottom casting or toe plate. By this construction the whole mass of the concrete is held together, and must tip bodily about point A before the crane can capsize. The calculation is simply a balancing of moments; if the crane radius is 18 ft., and the dimension B is 4 ft. 3 in., then the forward moment tending to upset the crane is 5 tons $\times$ 13·75 = 68·75 ft. tons; whilst the backward moment is the weight of the crane itself, $5\frac{1}{2}$ tons $\times$ 2·5 ft. = 13·75 ft. tons, plus the concrete, 8·5 ft $\times$ 8·5 ft. $\times$ 7 ft. = 505·75 cub. ft. = 28 tons $\times$ 4·25 ft. = 119 ft. tons; adding the two backward moments together, 13·75 + 119 = 132·75 ft. tons, showing a margin of safety of about 100

per cent., which is ample for this class of crane in average soil.

For heavy cranes erected on treacherous or indifferent soil, it is necessary to prepare extensive and costly foundations. Heavy piling or even sinking of concrete cylinders becomes necessary in order to prevent the settling of the great masses of concrete required for stability.

Deck cranes have the centre post extended to a lower deck level where the step is fixed. *See* **Deck Crane**. A note on the foundations for Fairbairn cranes will be found under **Fairbairn Crane**. The arrangements for the reception of a fixed crane upon a steel or timber jetty depend naturally upon the construction of the latter, but broadly speaking, a framework must be arranged to receive the main bedplate, and carry its loads to a group of piles, while a toe plate is fitted to suitable cross beams to take the bottom of the centre post.

Foundry.—The department in which cast work is produced. See descriptions under specific heads.

Foundry Crane. — A top-supported crane of simple framework consisting of mast, jib, and strut. The jib is horizontal, is fitted with rails, and provided with a traversing jenny or carriage; the strut springs from the base of the mast and supports the jib at about midway along its length. The gearing is arranged at the base of the mast, and may be operated by either hand, steam, electricity, or compressed air. The capacity of foundry cranes varies from 1 ton to 20 tons, but the larger sizes are now giving place to overhead travellers. The frames of foundry cranes are made either of timber or of mild steel; cast iron has been used, but not of late years. In cases where a support for the upper pivot pin is not convenient, the crane is made independent by fitting a central post which enters a suitable concrete foundation, and forms a pivot around which the crane revolves.

Fig. 55, Plate IV., shows an electric foundry crane of 5 tons power, and working radius of 14 ft. 9 in. The upright revolves around the column, supporting a traveller runaway, rollers being fitted. Lifting is done either by the motor, or by hand gear, the latter being sometimes advantageous in manipulating boxes delicately. The racking and slewing motions are effected by hand as the load is inconsiderable.

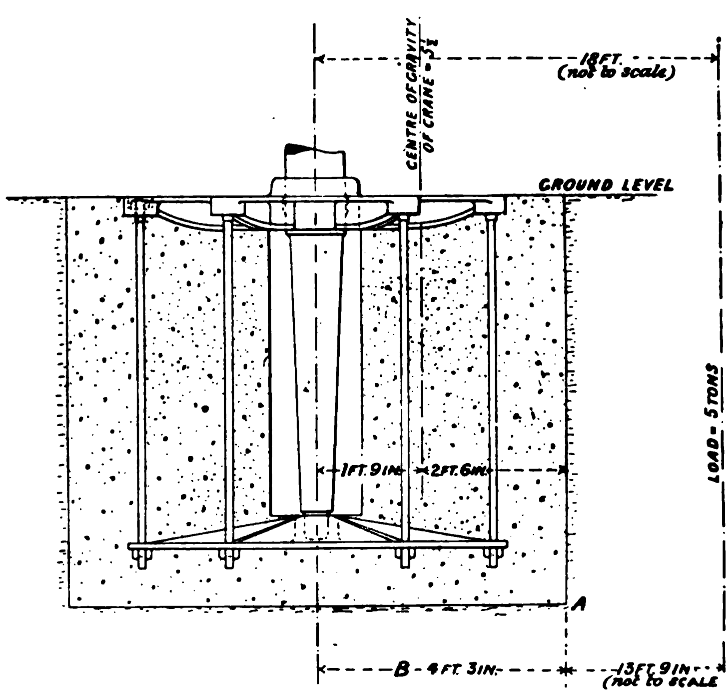


Fig. 54.—Crane Foundation.

Foundry Pig.—*See* **Cast Iron**.

Fourneyron Turbine.—The first turbine made, of French origin, but one which has become to a large extent displaced by improved types. It is of radial outward flow design, the water entering within the guide ring, and passing through it into the buckets. It is a reaction wheel working drowned, and has its shaft vertical. Generally there are three rows of buckets in one casting separated

by plane webs, and which thus constitute as many turbine rings. A sliding governor ring controls the supply of water so that it may be admitted to one, two, or all three rings, or to a part of a ring.

Four-way Valve.—This is used for working hydraulic presses, to put the top and bottom of the ram alternately in connection with the pressure main, at the same time opening access to the discharge pipe from the opposite face of the ram. In the early presses, four separate wheels or levers had to be moved to effect the movements, and risk of mistakes was thereby introduced, which would result in bad accidents. This difficulty is got over by making the valve in one casting, with a single lever or handwheel for operating, the movement of which diverts the pressure water into one or another passage, at the same time opening the correct exhaust pipe. A false movement is therefore rendered impossible. In the Stratton valve, a handwheel spindle has two valve faces upon it, which are made to press either in front or behind, according to which way the wheel is turned. A **Gas Reversing Valve** is often of four-way type.

Fractions.—A *proper* fraction is one whose denominator, (the lower number), is greater than the numerator, (the upper number), as $\frac{4}{5}$.

In an *improper* fraction the numerator is greater than the denominator, as $\frac{7}{4}$; such a fraction is equal to a whole number plus a fraction, and its value is seen on dividing the numerator by the denominator, $7 \div 4 = 1\frac{3}{4}$. In this form it is called a *mixed number*.

A mixed number is reduced to a fractional form by multiplying the whole number by the denominator of the fractional part, and adding to this product the numerator of the fractional part for the new numerator; the new denominator will be the denominator of the fractional part. Thus $7\frac{5}{6} = (7 \times 6) + 5 = 47$; the fraction then becomes $\frac{47}{6}$. Actually we are adding the number of sixths in 7 whole numbers ($=42$ sixths) to the 5 sixths of the fractional part.

Such a fraction as $\frac{3}{6}$ evidently $= \frac{1}{2}$, and in this state is said to be in its *lowest terms*. In some cases, however, it is not possible to see by inspection whether the fraction is in its lowest terms, or by what number it may be cancelled. Thus $\frac{203}{232}$ may be cancelled by 29 and $= \frac{7}{8}$. To find the proper number, (as 29 in this case), by which **Cancellation** may be carried out, *see* **Greatest Common Measure**.

To *multiply* fractions together, multiply all the numerators together for the new numerator and all the denominators together for the new denominator—$\frac{4}{5} \times \frac{2}{3} \times \frac{1}{3} = \frac{4 \times 2 \times 1}{5 \times 3 \times 3} = \frac{8}{45}$. $3\frac{1}{2} \times 1\frac{2}{3} \times 7 = \frac{7}{2} \times \frac{5}{3} \times \frac{7}{1} = \frac{245}{6} = 40\frac{5}{6}$. (When a whole number occurs without a fractional part, as 7 in the last example, it may be represented as a fraction by giving it a denominator of 1.) A fraction of a fraction, sometimes called a compound fraction, is found by multiplication:- $\frac{1}{2}$ of $\frac{3}{4} = \frac{1}{2} \times \frac{3}{4} = \frac{3}{8}$.

To *divide* fractions, invert the divisor and proceed as in the rule for multiplication. $\frac{8}{9} \div \frac{3}{4} = \frac{8}{9} \times \frac{4}{3} = \frac{32}{27} \times 1\frac{5}{27}$. $4\frac{1}{2} \div 5 = \frac{9}{2} \div \frac{5}{1} = \frac{9}{2} \times \frac{1}{5} = \frac{9}{10}$. Instead of using the sign $\div$ to denote the process of division, the fractions in the above examples may be placed thus:—$\frac{\frac{8}{9}}{\frac{3}{4}}$ and $\frac{4\frac{1}{2}}{5}$.

A knowledge of the above processes of multiplication and division of fractions is necessary in calculating gears for screw cutting.

To *add* and *subtract* fractions, they must have a common denominator. Thus $\frac{4}{7} + \frac{2}{7} = \frac{4+2}{7} = \frac{6}{7}$ and $\frac{4}{7} - \frac{2}{7} = \frac{4-2}{7} = \frac{2}{7}$, but an example such as $\frac{4}{5} + \frac{3}{8}$ cannot be worked as it stands, for fifths and eighths are dissimilar fractions. But $\frac{4}{5} = \frac{32}{40}$ and $\frac{3}{8} = \frac{15}{40}$, $\therefore \frac{4}{5} + \frac{3}{8} = \frac{32}{40} + \frac{15}{40} = \frac{32+15}{40} = \frac{47}{40} = 1\frac{7}{40}$. The number 40 is called the **Least Common Multiple** of 5 and 8, and the method of finding it for any set of numbers is described under that term. The fractions are then reduced to a common denominator, and the numerators added or subtracted as the case may be.

PLATE IV.

Fig. 55.—5-Ton Electric Foundry Crane.
(Ransomes & Rapier, Ltd.)

Fig. 57.—1-Ton Friction Hoist.
(Jessop & Appleby Bros., Ltd.)

Fig. 65.—4-Ton Steam Gantry Crane. (Ransomes & Rapier, Ltd.)

To face page 54.

Vulgar fractions are changed into equivalent decimal fractions by dividing the denominator into the numerator:—

$$\frac{5}{8} = 5 \div 8 = 8\overline{)5\cdot} \quad \underline{\cdot625} \qquad 2\tfrac{3}{4} = \frac{11}{4} = 4\overline{)11\cdot} \quad \underline{2\cdot75}$$

Frame Saw.—A frame saw may be either a **Bow Saw**, or a **Log Frame Saw**.

Francis Turbine.—A very successful type by an American inventor of that name. It is, as made at present, a pressure or reaction turbine, in which the water enters the wheel radially,

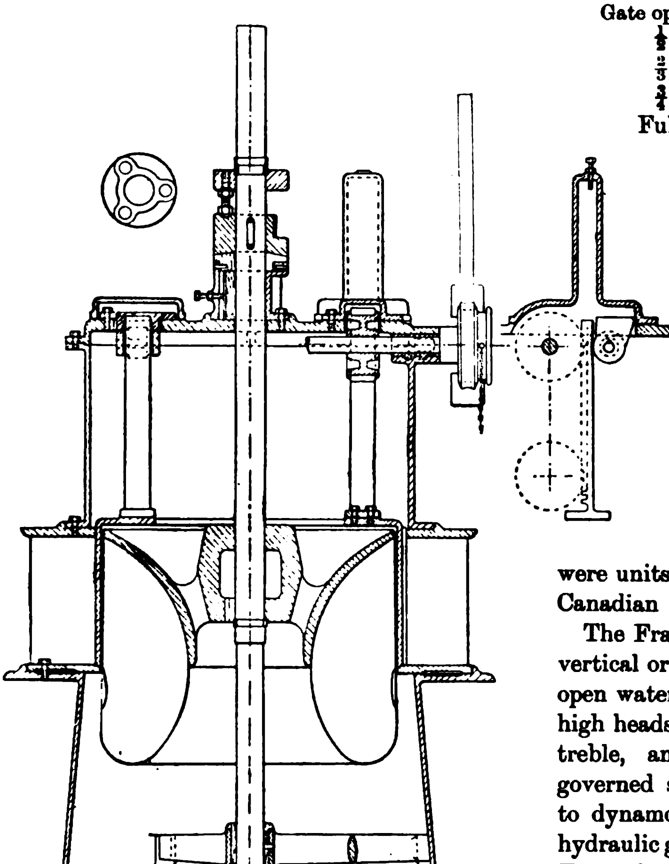


Fig. 56.—Francis Turbine. (Jens Orten-Böving.)

flowing towards the centre, whence it is deflected by curves in the buckets to be discharged in both axial and radial directions, Fig. 56. It has therefore been likened to a Fourneyron reversed, but with the further difference of mixed flow, that is, the radial flow is changed into an axial flow, while the water is in the buckets, instead of after it has been discharged from them. It is governed either with pivoted guide vanes or by a cylindrical gate, by means of which the orifices in the guide wheel are simultaneously increased or decreased in area, while an efficiency as high in some cases may be obtained at half gate as at full gate, thus:—

Schaffhausen Installation. Two Francis turbines.

Net fall, 13·6 feet. 434 HP. 169 revolutions per minute.

Gate opening.	Efficiency.
½	77 per cent.
⅔	82·6 "
¾	84 "
Full	86·6 "

Reutte Installation. One Francis turbine.

Net fall, 322 feet. 1,050 HP. 500 revolutions per minute.

Gate opening.	Efficiency.
½	75 per cent.
¾	80 "
Full	79 "

The largest turbines yet made, those for the Niagara Falls power companies, are Francis types. The first installed on the American side were units of 5,500 HP., the later ones on the Canadian are of 10,000 HP.

The Francis turbines are suitable either for vertical or horizontal axes. They are used with open water chambers or enclosed in casings for high heads. They are made with single, double, treble, and quadruple wheels, and can be governed so readily as to be coupled directly to dynamos. Their speed is regulated with a hydraulic governor, or with an oil pressure type. Even though the load is varied suddenly by 100 per cent. or more, the speed variation varies only by from 3 to 8 per cent.

Free Air.—Air at atmospheric pressure as distinguished from air under pressures artificially produced.

Freezing.—When a liquid is cooled to a certain temperature it becomes solid. The process of changing its state is called freezing,

and the point at which the change occurs is the "freezing point." The freezing point of water has been adopted as one of the fixed points in thermometer scales, being marked 0° on the Centigrade, and 32° on the Fahrenheit thermometer.

Freezing may be produced artificially by processes based on the principle that when a solid changes into a liquid, or a liquid into a gas, heat disappears. The following table gives a useful list of freezing mixtures, with the fall of temperature (Centigrade) produced:—

Substances.	Prop. by Weight.	Fall of Temp.
Water + Ammonium Nitrate	1 : 1	26°
Snow + Common Salt	3 : 1	20°
Snow + Calcium Chloride	7 : 10	55°
Sodium Sulphate + Hydrochloric Acid	8 : 5	28°
Ether + Solid Carbon Dioxide	...	77°

The term freezing point is applied to the temperature at which a metal or alloy begins to crystallise or solidify. This is not simple of determination, because there is a range of temperatures in most cases between that at which one constituent of an alloy begins to crystallise, and that at which the **Eutectic** solidifies. It has been proposed to term these the higher and the lower freezing points respectively. The strength of an alloy may be increased by adding a small quantity of another metal which shall have the effect of rendering the eutectic less fusible. The strongest alloy in the copper-zinc series, namely 60 of copper and 40 of zinc, has practically only one freezing point.

Frequency.—The rapidity of alternation or change of direction of the currents in an alternating current circuit.

The sign for frequency is ~, and it is referred to as the number of frequencies, or periodicity, or ~ per second.

Friction.—Friction is the resistance encountered when one body slides over another. Its tendency is to prevent motion taking place, or to arrest existing motion, the degree in which this tendency is exerted depending on the roughness of the bodies in contact. Nothing in Nature, however, has an absolutely smooth surface.

The friction between two bodies (*a*) is independent of the area of surface in contact, but (*b*) is directly proportional to the perpendicular force which presses the bodies together. The fraction $\frac{F}{R}$, where F = amount of friction, and R the perpendicular pressure, is called the **Coefficient of Friction.** For any two substances it may be found experimentally as described under that head, and is constant for those two bodies within certain limits, *i.e.*, moderate pressures and speeds of rubbing. The coefficient decreases with high velocities, and is also affected by temperature and extreme pressures.

In brakes, straps, driving wheels of locomotives and cars, &c., friction is advantageous. In other cases it is inimical, resulting in serious abrasion and heating of surfaces in contact. Lubricants are used to lessen these ill effects and, where lubrication is generous, as with an oil bath, the laws stated above are considerably modified—the laws of solid friction are superseded by those of fluid friction, which may be summarised as follows:—(*a*) friction is proportional to the area of wetted surface; (*b*) at low speeds friction is proportional to velocity, but above a certain "critical" speed, resistance = area of surface × a coefficient × velocity^2; (*c*) friction is largely independent of the character of the surfaces; (*d*) friction is independent of the pressure to which the liquid is subjected.

These laws differ considerably from those of solid friction, and are applicable to bearings running in a bath of oil. Journals and collar bearings slightly lubricated follow more closely the laws of solid friction.

Since rolling offers less resistance than sliding friction, rollers and ball bearings are used instead of ordinary bearings; but for the various mechanisms directly connected with the friction between surfaces, *see* **Belting, Belt Drop Hammer, Brakes, Clutches, Sellers' Discs, Shafting.**

Friction, Coefficient of.—*See* **Coefficient of Friction.**

Friction Hoist.—A form of hoist used largely in warehouses and flour mills for

hoisting goods from the street level up to the various floors. It is generally used in conjunction with a wall jib crane, or a cat head. The hoist itself consists essentially of a drum driven by means of a pulley or wheel which is rotated by reason of friction set up between it and its driving pinion. The face of the wheel may be either flat or grooved. Power is very frequently supplied by a belt drive on to the pinion shaft, but of late years electricity has become a convenient and economical source of power.

A typical hoist is shown in Fig. 57, Plate IV., operated by electric motor; the frame is of cast iron held together by a bottom bedplate casting, and by top tie bolts; an electric motor is secured to the bedplate and drives the pinion shaft by means of two gear reductions, these gears being machine cut. The motor speed is about 1,200 revolutions per minute. The drum is fitted with eccentric bearings and is moved eccentrically by means of a lever and cord. This movement places the large wheel in contact with its pinion, and the barrel is then revolved upon the shaft. Upon releasing the cord, the wheel passes from contact with its pinion to contact with a brake block arranged overhead. As shown in the illustration, the load on the drum always tends to pull the wheel on to the brake block. These hoists can be arranged in almost any position in a warehouse, and the load chain led to the cat head, or jib as the case may be. The motor is shunt wound and runs continuously whilst the hoist is being used.

Friction Wheels.—Wheels which take the place of toothed spur and bevel gears. They transmit power either by the friction of plane smooth surfaces, or of interlocking rings, the sectional shape of which is that of truncated wedges. The latter are cast, but plain friction wheels run either wood to iron, or are covered with paper, or have their thickness built up with discs of timber retained with metallic plates. **Disc Feed** is a common type of friction feed.

Front Slide Lathe.—A type of small lathe which has the guiding ways for the rest upon the front face of the bed instead of on the top. The advantages are, that the carriage can be moved past the poppet when required, leaving clear space for hand operations; the cuttings cannot rest upon the ways, but fall away from them, and the lead screw pulls at the centre of the carriage instead of to one side. Perhaps a greater advantage still is that the design of the rest permits of fitting a vertical slide, which is of great value in tool making and scientific work, for milling, wheel cutting, &c., in combination with a division plate on the headstock mandrel.

Frosting.—The scraping performed for ornament only on engineers' bright work. It presents a number of facets to the light, with pretty effect.

Fuels.—In its wider acceptation any substance that will unite with oxygen with the production of heat may be termed a fuel; but in engineering parlance a fuel is either wholly composed of carbon, or of hydrogen, or of compounds of these two substances, more or less mixed with undesirable impurities of a mineral nature, or with water. Fuels are to be classed under three main heads of solid, liquid, and gaseous. Of the solid fuel the chief is coal, in which class may be included lignite, and even peat, though both these latter are only partially removed from their original vegetable condition. Next come wood, straw, corn, nuts, and many vegetable substances, some of which, as corn or maize, are used only occasionally, though the husks are more properly usable under agricultural boilers. Straw and megass or sugar-cane refuse are largely used. Artificial solid fuels are employed either as coke, which is coal from which the hydrocarbons have been distilled, or as briquettes, which consist of small or dust coal agglomerated by pressure or heat, or both, into solid blocks by the aid of pitch or other agglomerates of a suitable nature. Of liquid fuels the chief supply is the crude mineral oil obtained from boreholes in the earth. From the crude oil are obtained the various lighting oils and the petrols, and all these mineral products are practically pure fuels, that is, they are almost wholly combustible. Other liquid fuels in fairly common use are tar, creosote oils, blast furnace and coke oven oils, and other products of the distillation of coal. Vegetable oils as well as animal oils may be employed as

fuel, but their use is generally confined to lamps, for such oils have other uses for which they command prices that put them out of the range of commercial fuels.

A liquid that contains an element of water chemically combined with hydrocarbon is alcohol, the price of which is not so great as to debar its use in small motors, and for special purposes. It is much less offensive than petrol. Gaseous fuel is found in Nature as a product of the oil wells, but most gaseous fuels are artificially prepared from solid or liquid fuels by destructive distillation by heat, or by partial combustion of solid carbon with one atom of oxygen, whereby the carbon is converted into carbon monoxide gas, and still retains more than two-thirds of the heat potential of the original carbon so far as useful effect is concerned.

In burning fuels the tendency is for the best results to be obtained the more nearly a fuel is made to approach the physical condition of a gas. Thus solid fuels may be and are ground to a fine dust, and burned in intimate admixture with a volume of air; liquid fuel is similarly atomised by an air or steam jet, and burned in a stream of air. Perfect combustion, in fact, depends upon an intimate admixture of the fuel with the oxygen requisite to burn it, and the more intimate the mixture, the less will be the volume of oxygen or air required. In the burning of fuel the highest temperature is obtained by the use of oxygen, but oxygen is not a commercially available gas, and air is alone practicable. Since air contains only about one-fifth its weight of oxygen, the temperature attained cannot exceed about one-fourth of what would be attained with pure oxygen. The difficulty of thoroughly mixing the air and fuel within the space and time usually available renders necessary from 20 to 100 per cent. more air than is chemically indicated, with a corresponding further reduction of the temperature of combustion. Temperature is, in fact, a compromise between the calorific capacity of the fuel, the specific gravity of, and total weight of the products of combustion, plus the excess of air. When specially high temperatures are sought, attention must be given to the use of the smallest possible quantity of air consistent with complete combustion, and to the heating of this air either by the waste gases from the furnace or by other means, for the ultimate temperature with any fuel will be practically always a certain amount above the initial temperature of the air supply. Thus if a fuel will give a temperature of 2,000° Fahr. with air supplied at 50° Fahr., it will give 3,000° if the air be supplied at 1,050° Fahr. And if a given temperature is desired from a poor fuel gas that will not give that temperature however much of it may be burned at one spot, yet the desired temperature may be attained if a portion of the gas is burned where the high temperature is reached, and another portion be burned in two chambers of brick chequer work alternately, through which the air supply to the first portion of gas is alternated with the combustion of the second portion of gas. That is to say, one portion of gas is used simply to heat bricks, which in turn heat the air supply for the second portion of gas.

When a fuel such as bituminous coal consists of an unknown compound of solid carbon, and hydrocarbons capable of being driven off by heat, the absorption of latent heat by the vaporising of the hitherto solid hydrocarbons is so great that the incandescent fuel on the grate cannot maintain a very high temperature. The gas and vapour driven off are also comparatively cold, and burn with difficulty in a boiler furnace, all or a part of the walls of which are water-cooled. Black smoke is then formed, the hydrogen burning at a lower temperature than the carbon which is set free as soot, and will burn in the hydrogen flame if there is the requisite air present, and the furnace is lined with a refractory material such as brick in order to keep up the temperature to that necessary for the act of combustion. There can be no complete combustion of hydrocarbon gases unless the important point of temperature is fully provided. At the same time a very small amount of bituminous fuel even when burned in a fire-brick furnace of correct shape will produce dense black smoke if there is not a sufficient draught above the fire to supply a sufficient volume of fresh air to burn the evolved gases. This is specially

noticeable when the fire is so thick that no free oxygen gets through it.

See **Calorific, Coal, Gaseous Fuel, Liquid Fuel, Specific Heat,** &c.

Fulcrum. — The fixed point on which a lever moves. *See* **Levers.**

Full.—Has numerous significations. It denotes a dimension very slightly large, as the difference between an easy and a driving fit. The full of an eccentric is the larger part of the sheave; full bore is that of a valve or waterway for delivery when it is equal in area to that given by the valve lift in the bore of the suction; full gate denotes the fact that the buckets of a turbine are widely opened to their largest possible capacity instead of being worked at part gate. Full gear means that the valves and links of an engine are set to admit steam throughout the entire piston stroke. A drawing is made to full size when it represents objects of the actual dimensions, *i.e.*, not to scale. A full thread is one that is cut sharply without broken or topped edges.

Fullering.—The reduction of forged work, Fig. 58, A, B, C, with a tool or tools having convex edges—*fullering tools*. The reduction is effected more rapidly than if done with a sledge, or a set hammer. It is only a roughing operation, since the ridges left by the fullering tools have to be obliterated by the set hammer or flatter, Fig. 59. Fullering, therefore, is the first stage in drawing down, and usually applied only to bars of rectangular section, since round bars are better reduced by hammer blows direct which operate on narrow arcs only at once.

When drawing down a rod or bar, the blows are always delivered in a direction away from the hand holding the work, never towards it.

The top fuller is handled with a rigid rod, or a flexible withy; the bottom one is generally an anvil fuller, having a stem to fit the anvil hole. Fullers are also embodied in the spring form of tool similarly to swages.

Fullering is essentially work for the anvil. Under power hammers reduction is generally effected at once between tup and anvil, or between dies, instead of putting the work through the intermediate stage of fullering. Sometimes, however, when the amount of reduction is considerable, and the mass rather large for the hammer, a round bar is used as a fuller, Fig. 58, D. It is moved over the work and struck by the tup, so producing the indentations desired,

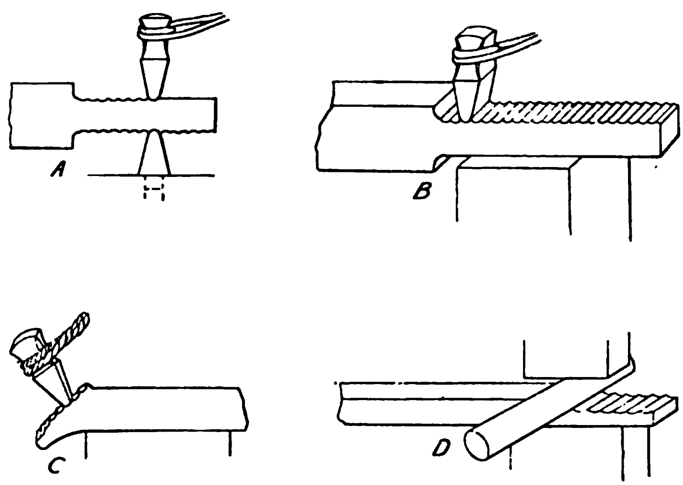


Fig. 58.—Fullering.

after which the surface is flattened with blows delivered by a flatter, or directly by the tup.

Fullering also denotes broad caulking, or caulking which covers the whole, or nearly the entire edge of a plate. It is often adopted to the displacement of narrow caulking, which is liable to produce grooving of the plate adjacent.

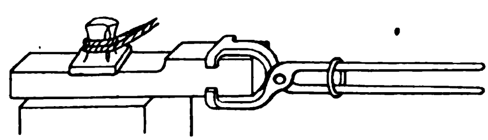


Fig. 59.—Flatter.

Furnace.—Furnaces are distinguished by their functions, shapes, or methods of operation, or by names. If by their functions they take the name of the metals or alloys reduced or melted in them, or other uses, as brass, iron, Bessemer, open-hearth, &c. If by their shapes, we have cupola, pear-shaped, reverberatory, or arched, cylindrical, corrugated, &c. If by their methods of operation, air blast, electric, forced

draught, regenerative, and so on. By names of inventors, as Bessemer, Siemens, &c.

The chemical reactions which go on in furnaces are an essential feature in the reduction and melting of metals and alloys. Akin to these are the nature of the refractory linings used. In boiler furnaces the combustion and rendering up of heat to the water open up many problems. Around melting furnaces a vast quantity of plant and machinery gathers for air and gas supply, heating, charging, tapping, &c. The principal subjects involved in the study have separate treatment in these volumes.

Furnace Fittings. — These comprise in steam boilers the furnace front and its doors, the dead plate, fire-bars, and bearers, and the bridge.

Furnace Flues.—The reasons why plain cylindrical furnace flues have been abandoned in boiler practice are stated in **Cylinders—Strength of.** The modern furnace flues differ from the older in being so designed that they are practically a series of short tubes. The reason of this is obvious, since the collapsing strength of short tubes has been found to vary inversely as the length, and therefore this shortening increases strength to resist collapse.

The first attempts in this direction were crude, but familiar enough to the old engineers. The plain flues were encircled at intervals with hoops of plain rings, or angle, or tee iron. This was efficient in a limited sense, but elasticity was deficient, and deposit accumulated under the rings. A better plan was the encircling and union of tube lengths with rings of tee iron, which also were deficient in elasticity. The first successful solutions came with the Adamson flanged seam patents, and the Bowling hoop, and other devices based on flanging, and corrugation respectively.

In the *Adamson* seam (Fig. 60, A), the flue tubes are made in short lengths flanged outwardly with a large radius, and riveted through a caulking ring. B is a later design, an *absorber* seam, which allows greater elasticity, but involves flues of different diameters, away from the furnace portion. In the *Bowling* or *Bolton* hoop, C, the short tubes are united with rings of an arched section. These two types divide favour in Lancashire and Cornish boilers, with little rivalry, and in many marine boilers. An advantage of the Adamson seam is that the flanging puts a severe test on the ductility of the material, which necessitates the use of a suitable quality.

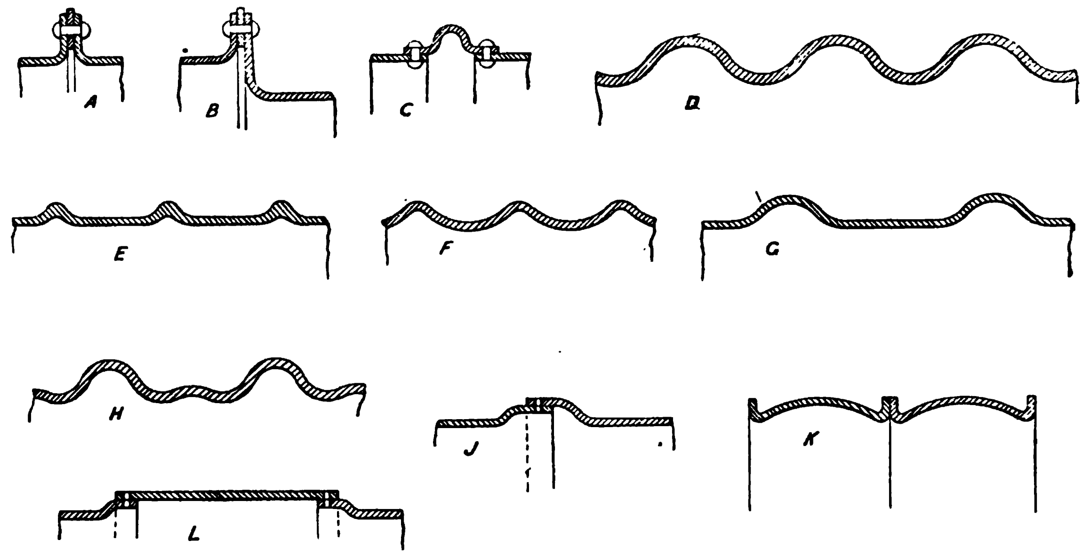


Fig. 60.—Furnace Flues.

The Board of Trade conditions for Adamson's seams are these :—

The radii of the flanges on the fire side should be about 1½ in. The depth should be three

times the diameter of the rivet, plus $1\frac{1}{2}$ in., and the thickness of the flanges be retained as nearly that of the plate thickness as possible. The distance from the edge of the rivet holes to the edge of the flange should not be less than the diameter of the rivet, and the diameter at least $\frac{3}{8}$ in. greater than the thickness of the plate. The depth of the ring between the flanges should not be less than three times the diameter of the rivets. The edge of the ring next the fire should be at about the termination of the curve of the flange, and the thickness not less than half the thickness of the furnace plate. The rings should be turned.

The Board of Trade rule for Adamson's seams, using steel of from 26 to 30 tons tensile strength, is as follows :—Providing the length in inches between centres of the flanges of the rings is not greater than $(135T - 12)$

$$WP = \frac{8800 \times T}{3 \times D} \times \left(5 - \frac{l + 12}{67{\cdot}5 \times T}\right)$$

where WP = Working pressure in lb. per square inch.
T = Thickness of plate in inches.
l = Distance between centres of flanges in inches.
D = Diameter of furnaces in inches outside the plates.

As the Adamson seam and Bowling hoop have revolutionised Cornish and Lancashire boiler practice, so the invention of the *corrugated flue* has done the same for the larger marine boilers. Its invention was due to M. Renouf in 1853, the object being to obtain an increase in heating surface. Mr R. Wilson mentions having seen a corrugated tube plate previous to 1872, and remarked that it had been proposed to strengthen tubes by making them of corrugated plates. Mr Morison patented his flue tube in 1870. In 1878 Mr Fox introduced his corrugated flue, shown at D, after which this type came rapidly into favour : first the Fox form with regular corrugations, and then others with differences.

The Purves' *ribbed flue*, Fig. 60, E, is not a corrugated one, but one thickened with ribs thicker than the tube plate.

The Morison flue, F, has unequal corrugations, those of small radii facing toward the water, and the alternate ones of large radii toward the fire. It is claimed that deposit does not lodge so readily on their surfaces, as on the deep corrugations facing toward the fire in the Fox flue, and that it is easier to clean.

The Farnley flue has its corrugations diagonally instead of at right angles with the axis. Increased rigidity is the claim made for these.

There are several other flues which embody obvious principles desirable in a flue, but which do not admit of classification.

In the Holmes flue, Fig. 60, G, plain cylindrical portions and corrugations alternate, the pitch of the latter being about 16 in. H is the Deighton flue, which has a swell between the corrugations to resist collapse. These were introduced in 1889. Paxman's flue, J, is composed of plain sections terminating in socket and spigot fittings. Arnold's furnace flue, K, is formed of a series of short barrel shaped hoops, flanged like the Adamson seam, and riveted, with or without caulking rings. The flue of Hawksley, Wild, & Co., Ltd., L, is made of alternating larger and smaller tubes, the latter having their ends expanded to fit spigot fashion into the larger.

Lloyds' rules for the principal furnace flues are as follows, where

D = Outside diameter of furnace in inches.
T = Thickness of plates in inches.
L = Length of plain cylindrical part in inches measured from the centres of the rivets connecting the furnaces to the flanges of the end and tube plates, or from the commencement of the curvature of the flanges of the furnace where it is flanged or fitted with Adamson rings. The steel is understood to have a tensile strength of 26 to 30 tons.

For corrugated furnaces made of steel, on Fox's, Morison's, Deighton's, or Beardmore's plan, to be calculated from

$$\frac{1259 \times (T - 2)}{D} = \text{working pressure in lb. per sq. in.}$$

For Brown's cambered, and improved Purves' furnaces (with ribs 9 in. apart),

$$\frac{1160 \times (T - 2)}{D} = \text{working pressure in lb. per sq. in.}$$

For spirally corrugated furnaces,

$$\frac{912 \times (T-2)}{D} = \text{working pressure in lb. per sq. in.,}$$

where T = thickness of plate in sixteenths of an inch,

and D = outside diameter of corrugated furnaces, or smallest outside diameter of ribbed furnaces in inches.

For Holmes' patent furnaces, in which the corrugations are not more than 16 in. apart from centre to centre, and not less than 2 in. high,

$$\frac{945 \times (T-2)}{D} = \text{working pressure in lb. per sq. in.,}$$

where T = thickness of plain portions of furnace in sixteenths of an inch.

D = outside diameter of plain parts of the furnace in inches.

Furnace Jack.—For setting up the collapsed crowns of boiler furnaces, a special design of jack is devised. It has a cylindrical body, with two side bosses, carrying large screws, which reach to the furnace sides, and centre and steady the jack. The bottom of the jack stands on an iron block curved to match the furnace, and the ram presses up under another block. On pressure being applied, the top block is forced against the collapsed part, causing it to resume its normal shape. The two lateral screws already mentioned prevent the furnace sides from being pulled inwards, and becoming distorted in shape. In another style, side rams occupy the place of the screws, and perform their functions. The jacks range in power up to 200 tons.

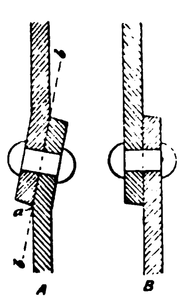


Fig. 61.—Furrowing.

Furrowing. — Furrowing occurs close to the inner edges of lap joints below water line, and around the edges of plates which are insufficiently stayed. Looking at the lap joint, Fig. 61, it is easy to see why mechanical movement takes place. The tendency of pressure alternating with the removal of pressure will be to bend the joint in alternate directions and so produce incessant stresses in the plate at *a* close to the seam, exposing a line of clean metal to the action of acidulated water. Lap seams are made as shown in both figures, A and B, but in whichever way they are made the tendency when under pressure is to assume the other form, so that the angle which the face *bb* of the joint makes with the centre lines of the plates will be constantly varying. Nearly all the explosions of the barrels of locomotive boilers which have been recorded have been due to furrowing or grooving.

Fuse—*Electrical.*—An appliance placed in an electric circuit to prevent the passing of heavier currents than the conductors or the apparatus they supply can safely carry.

A fuse consists of a wire or strip of metal of such size and material that whilst it will safely carry the normal current of the circuit, a dangerous excess from overload or short-circuit will raise its temperature to a point at which it will melt and automatically interrupt the circuit.

On low tension systems, up to 110 volts, open fuses of wires made from an alloy of tin and lead are used. Above this pressure, fuses protected by porcelain covers, or tubes of incombustible material, are employed. Totally enclosed fuses are now much used, consisting of a tube with metal ends forming spring clip or clamping terminals, joined together inside the tube by suitable fuse wires, the tube itself being filled with sand or dust. All fuses should be covered, in order to prevent the flying of molten metal when they blow, and also to prevent the formation of an arc at the moment of failure. On high tension circuits, where dangerous arcs might be maintained, fuses are often so arranged that the ends of the melted wire are drawn down into an oil tank, when the arc is immediately quenched.

When a fuse blows it is often the practice to put in another and stronger one to prevent the recurrence of failure of the supply. This should never be done until the *cause* of its failure has been discovered. If this is not obvious, an ammeter should be used to determine the current required by the circuit, when, if the cables are competent for the safe carrying of the normal load, a fuse melting at 30 per cent. above this should be used. It should be remembered that a fuse is a safety device, and strengthening it is

equivalent to screwing down the safety valve of a steam boiler. For this reason fuse fittings calibrated by the manufacturer, and their contacts so arranged that one size of fuse cannot be placed in circuits of larger or smaller capacity than it is fitted to control, are much to be preferred to the use of bare fuse wires and open terminals or binding-posts.

Where open fuse wires are used, however, on circuits over 20 ampères capacity, copper fuse wires should be employed. The heating of a copper wire can either be observed at the time, or deduced from its oxidation when cold, so that warning of its overloading is given; when the circuit can be indicated, and steps taken to reduce the load or to strengthen the fuse as may be advisable, and the inconvenience of stoppage by its failure may be thus obviated.

Fuse—Blasting.—Explosives are fired by detonators or copper tubes filled with fulminate of mercury and potassium chlorate. This composition explodes rapidly and with great violence, and so immediately and effectively detonates the charge. The detonator in turn is fired by means of a fuse, and of these many types are in use.

The earliest types of fuses were unbroken straws filled with fine gunpowder, or the quick-match which consists of woollen thread dipped in a paste of gunpowder, gum, and water. Bickford's fuses are now almost universally used in blasting operations. These consist of a central core of fine powder enclosed by a double or treble covering of jute threads and made waterproof by an external covering of gutta-percha, or pitch. They are cut into 8 or 10 yard lengths and burn at the rate of one foot in thirty seconds. In the Bickford instantaneous fuse the core consists of cotton wick which has been passed through a paste of meal powder. It burns at the high rate of 450 feet per second. A still higher velocity of combustion, 5,500 yards per second, is reached in the detonating fuse invented by Hess, and consisting of cotton threads drawn through a paste of fulminate of mercury.

The friction fuse is an ingenious mechanical device invented by Colonel Lauer. A detonator is placed at the end of a metallic tube which is enclosed by another and paper tube. Adjoining the detonator is a mixture of potassium chlorate, and antimony sulphide, and in the midst of this composition is a jagged friction wire which passes through the length of the tube, and is connected with a cord passing over pulleys, &c., to a spot outside the danger zone. When the cord is pulled the friction of the wire ignites the composition and so fires the charge.

In many cases electrical firing has superseded the methods just mentioned. The priming mixture is ignited either by sparking or by the incandescence of a fine platinum wire connecting the ends of the terminals, which are

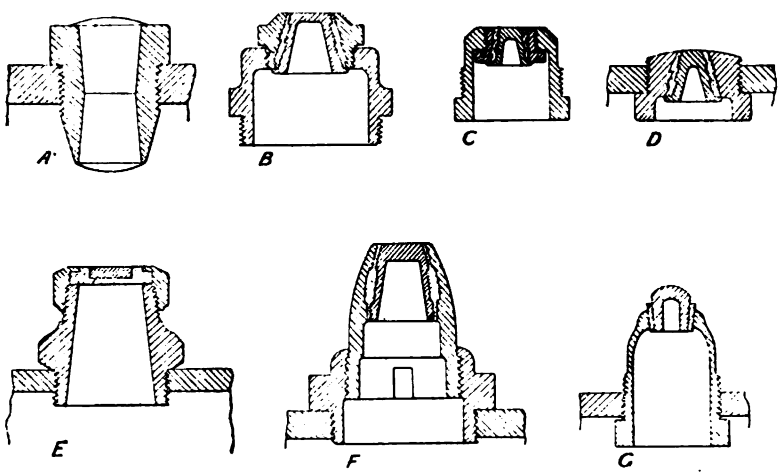


Fig. 62.—Fusible Plugs.

surrounded by the priming mixture. Many interesting machines have been devised for the electrical firing of a number of shots simultaneously.

Fusible Plug.—A plug of gun-metal screwed into boilers in various localities to give warning and put the fire out when overheating occurs. This occurs on the melting out of a fusible metal or alloy contained within the plug. Tin is the best metal to use, lead is often employed, and alloys are composed of tin and lead in various proportions, lead being usually in excess. The alloy should melt at about 400° to 450° Fahr., varied according to the temperature; a little higher than that corresponding with the steam pressure of a given boiler. There should be sufficient body of alloy in the plug, otherwise the discharge of water in case of accident will not be sufficient. The top must be cleaned from scale as often as the boiler is cleaned. Dependence must not be placed in one only. Plugs are put on furnace crowns and where the heat is most intense. The earlier style of plug, Fig. 62, A, is not very reliable because it cannot be depended on to thoroughly clear the fusible centre of the plug. Better forms are therefore designed, with metal centres held in by the fusible composition, so that heating results in the centre falling out and leaving a large aperture with certainty. Three types of the National Boiler and General Insurance Co., Ltd., are shown in B, C, D, a removable centre portion screwed into the plug holding the fusible alloy with its centre shouldered in. C and D are special patterns for locomotive boilers. Bailey's plug, E, has a copper cap let into the fusible metal, to protect it from the action of the boiler water. Another pattern by the same firm, F, has the central portion removable without taking the entire plug out. Williams' plug has also a metal centre, as seen at G, which drops out bodily.

G

G.—The symbol for **Gravity**.

Gab Lever.—A lever having a hook or notch at one end, to be readily detachable.

Gage.—*See* **Gauge.**

Gaggers, or Prods.—Blunt-pointed projections cast on core plates and loam plates to retain the loam securely. They are from $\frac{1}{2}$ in. to 1 in. long, by about $\frac{1}{4}$ in. or $\frac{3}{8}$ in. in diameter at the base.

Gallon.—A measure of capacity equal to 4 quarts. It contains 10 lb. of distilled water, or 277·274 cubic inches. The United States gallon is smaller, being but 231 cubic inches, the measure legalised by Queen Anne. Hence 59 imperial gallons equal about 71 U.S. gallons.

One gallon also equals 4·54 litres.

Galloway Boiler.—A type of boiler, Fig. 63, modelled on the Lancashire, but having a special design of flues, named after the Manchester firm of that name. Messrs Galloway have made several changes in its design since the year of its introduction (1849). The earlier boilers had furnaces of elliptical cross section, and the cone tubes were set vertically. These were soon discarded for the present form, with the furnace section having the top and bottom plates struck from a common centre, and the conical tubes set with their axes radially therewith. This, with the taper given, standardised the tubes, and rendered their insertion easy. *See* **Conical Tubes.** When this alteration was made, the well-known pockets A, at each side of the flue beyond the furnaces were substituted for a narrow neck previously made behind the furnace, and between it and the rows of Galloway tubes. The number of tubes has also been increased. The first boiler made had seven only. The present largest standard boiler has thirty-five, in a boiler 30 ft. × 8 ft. 6 in. Pressures as high as 200 lb. per square inch are employed. More than twelve thousand of these boilers had been constructed up to the end of 1902. The Galloway boiler has greater evaporative capacity than the ordinary Lancashire, because the heating surface of the cone tubes lies directly in the course of the flame and hot gases.

Galloway Tubes.—*See* **Conical Tubes.**

Galvanic Action.—The production of electric currents by chemical means in a battery having zinc-copper elements.

If, in a vessel containing a dilute solution of water and sulphuric acid, a plate of zinc and a plate of copper are placed, upon their ends being connected by a thin copper wire, it will soon be observed that the wire becomes heated. This is caused by the passing of an electric current which is generated by the chemical action taking place in the "Galvanic Battery" or "Voltaic Cell" thus constructed, and is dissipated as heat in the wire.

During the working of the battery the zinc is consumed. The galvanic battery is thus a means of converting the element zinc into electricity, and is therefore more in the nature of a generator than the dynamo electric machine. The latter being driven by mechanical energy, supplied by an engine and boiler which utilise the potential energy of coal, the combination converts the coal to electricity through several stages, whilst the galvanic battery acts direct upon its equivalent zinc. The battery is therefore the most direct and simple, and is also the most efficient converter or generator. Considering a piece of machinery to be electrically driven, and working back in the one case through belting, motor, cables, dynamo, engine, and boiler to the coal, there will be a loss of 90 per cent. of the power actually in the fuel used, whilst in the case of the belting, motor, and a sufficient number of battery cells, the inefficiency losses will be only 30 per cent.

Thus the chemical is three times as efficient as the mechanical plant. But the cost of the zinc consumed in the battery would be at least

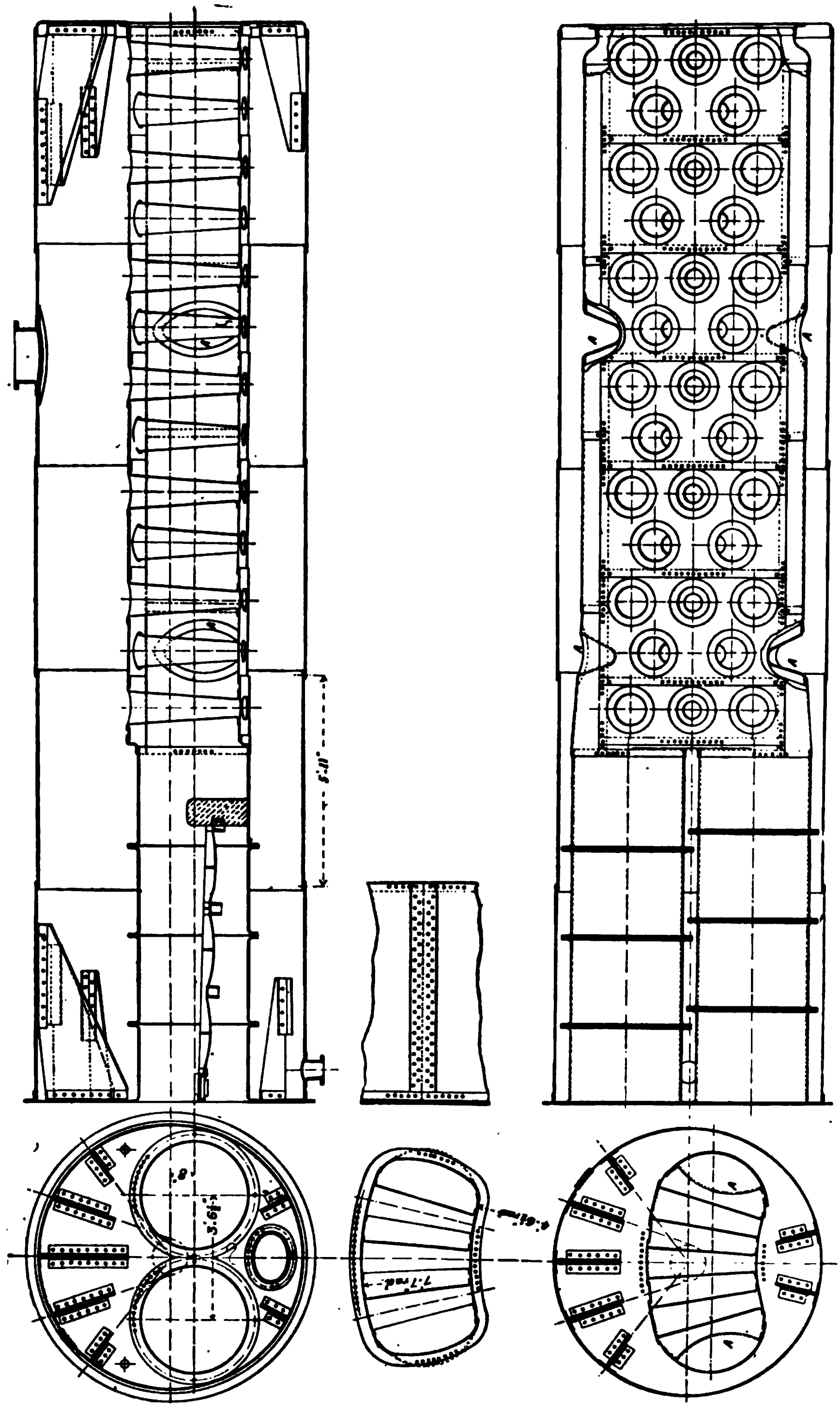


Fig. 63.—Galloway Boiler, 30 ft. by 7 ft. 6 in. (Galloways, Ltd.)

thirty times that of the coal per effective HP., so that even the most wasteful steam plant can supply the power required at a much less cost than any battery can do.

The galvanic battery is most useful, and is much employed in telegraphy, and in electro-medical apparatus; also, on account of its practically constant E.M.F., it is used as a standard cell for electrical testing and standardising instruments. *See also* **Batteries—Primary**. For Galvanic Action in boilers, *see* **Boiler Explosions**.

Galvanised Sheets — Galvanising. — Steel sheets coated with zinc to prevent corrosion. The term derived its name from the fact that zinc being electro-positive to iron, the two form a galvanic couple, the zinc being attacked first, and so preserving the iron.

In present practice the sheets, thoroughly cleaned, are first pickled in a bath of hydrochloric, or sulphuric acid diluted in water, for about twenty minutes, and at a temperature of about 90° Fahr. If the latter acid is used, the sheets are subsequently soaked in a tank of cold water, which is not necessary if hydrochloric is employed. They are then transferred to the bath of molten zinc—spelter—which is maintained at a temperature of 20° or more above the melting point. The regulation of temperature is most important, as the process may be delayed by too low, or the zinc oxidised by too high a temperature. The bath—of steel plate—is surrounded by, and rests above a brick-work body, within which a coke fire is kept burning, with provision for regulating the temperature.

The flux used is sal-ammoniac, placed on the surface of the molten metal, within partitions, one at each end. The sheets are guided by rolls in the bath, down into it at one end, through the flux horizontally along, and up out at the other end. The sheet must attain the same temperature as the bath before the zinc will adhere, so that the time of its transmission has to be varied with the thickness. The sheets are then dropped into a tank of water, followed by immersion in a second tank. The difference in the dull and the crystallised appearance of sheets is due to the immediate immersion, or to delay in the dipping respectively. The dipped sheets are then rubbed over with sawdust, and dried by coke fires, or in ovens. 1 lb. of zinc will coat a surface of 15 sq. ft.

Castings and forgings are frequently galvanised. The same treatment is adopted, except that the articles must be dipped singly instead of being passed through by rolls. If very small, a number can be dipped at once in wire baskets. The cleaner and smoother the castings or forgings, the better will they take the zinc.

Galvanometer.—An electrical instrument for indicating the presence, and measuring the quantity and pressure of electric currents.

A simple form of galvanometer is shown in the diagram, Fig. 64, which illustrates the

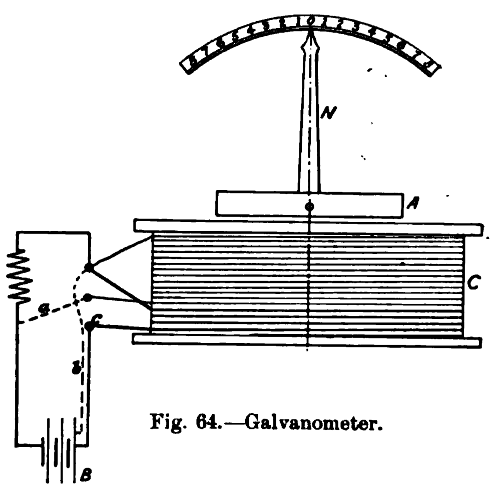


Fig. 64.—Galvanometer.

action of the instrument. The coil C is wound with insulated copper wire. In some instruments a double winding is used, one part indicating quantity, the other intensity of electricity passing. The armature A is pivoted to balance the indicating needle N at zero when the circuit is open. When a current from the battery B or other source flows through the coil, the armature is attracted at one end, and repulsed at the other by the north and south poles in the magnetic field created within the hollow coil, with the result that the needle is deflected over the scale. If the current is so applied as to produce a north pole at the right-hand end of the armature, the needle is deflected to the right, whilst if the flow is reversed it is deflected to the left hand. Thus the *direction* of current in any circuit may be tested after

having once determined which end of the winding gives a right-hand deflection when connected to the + terminal of a testing battery. As the tangent of the angle of deflection is proportionate to the strength of the field acting on the balanced armature, the scale may be calibrated, and the ampères passing deduced from the value of ampère-turns.

The *turns* being fixed, the deflection varies according to the different field strengths produced by a variation of *ampères* passing in the "Ampère Winding" of low resistance. If the high resistance winding be connected as a shunt (shown by dotted lines a, b) and the other winding disconnected at the terminal c, the E.M.F. may be measured.

For by Ohm's Law $\frac{E}{R} = C$, and R being constant, C will vary as E; E may therefore be deduced by the current indicated, and the instrument be calibrated as a voltmeter. Thus, referring again to the diagram, the *direction*, *quantity*, and *intensity* of the electricity supplied by the battery to the resistance × (which may be any electrical apparatus) can be indicated and measured.

A more delicately adjusted galvanometer has its moving part suspended by an extremely fine silk thread—this is called a "Suspensory Galvanometer." In this an *astatic pair* of magnetic needles is used, that is, two magnetised needles of equal strength and size are secured one over another in reverse positions as regards their polarity, so that the force which urges one to set itself in the magnetic meridian is counterbalanced by the force which acts on the other. Such a pair being independent of the earth's magnetism will remain in any position in which they are set, and will be readily deflected by a current flowing through a wire coiled round one of the needles. In another type the moving part carries a screen which reflects from a mirror a beam of light upon the scale—this is the "Mirror Galvanometer." Both these latter types are extremely sensitive and delicate instruments suitable only for laboratory work.

Gang Mill.—A term applied to a gang or set of milling cutters all arranged on one arbor, to tool intricate or irregular surfaces. In such cases the work could not be done with a single cutter, either owing to the difficulty or impossibility of making it.

Gang Saw.—*See* **Log Frame Saw.**

Ganister.—A highly silicious lining used for Bessemer converters, furnaces, steel moulds, &c., and containing from 92 to 95 per cent. of silica.

Gantry.—The elevated strutted framing, of timber or steel, supporting the rails upon which an overhead traveller runs.

Gantry Crane.—An overhead crane which has a Goliath type of travelling framing, but carries a jib crane instead of a crab. The crane is generally of fixed type, pivoted in a bed at one end, or at the centre of the gantry; but travelling cranes are also employed, running along the gantry beams on rails. The term generally denotes a crane mounted on a gantry of considerable length, corresponding to that of a Goliath. When short, the term portal crane is commonly applied. Gantry cranes are rarely operated by hand, and only in some few cases hydraulically. They are chiefly of steam, and electric types, the latter being the newer agency.

The value of the gantry crane lies chiefly in docks and harbours, for loading and unloading vessels. The tall gantry spanning the lines of rails does not interfere with the movements of the trucks. They are travelling cranes, and they are travelled generally by similar devices to the Goliaths, the framings of which they closely resemble. *See* **Goliath Crane.**

Fig. 65, Plate IV., illustrates a 4-ton steam travelling gantry crane of 7 ft. gauge, and of 19 ft. radius. The span of the gantry is 39 ft. to the centres of rails, the height of lift is 25 ft. The head room to the underside of the gantry girders is 13 ft. The speeds are: lifting, 80 ft. per minute; the crane traverses at a rate of 120 ft. per minute; and the travel of the gantry is 80 ft. per minute. The travel is by means of bevel gears, one set of which is seen at the left hand of the crane.

Gap Gauge.—*See* **Caliper Gauge.**

Gap Lathe.—The value of this old type of lathe, Fig. 66, Plate V., has been somewhat discounted by the increasing specialisation of tasks in modern shops. The face lathes have taken much of its work, and work between centres is more often appropriated by lathes without gaps. In the general shop it remains

PLATE V.

Fig. 66.—Ordinary or Fixed Gap Lathe. Fig. 67.—Sliding Gap Lathe.
(John Hetherington & Sons, Ltd.)

Fig. 72.—360 B.H.P. Vertical Gas Engine, direct coupled to Alternator.
(Campbell Gas Engine Co., Ltd.)

Fig. 75.—Gas Exhauster, driven by Steam Engine. (The Bryan Donkin Co., Ltd.)

To face page 68.

invaluable where spindles and shafts, wheels and pulleys, have to be done indiscriminately by the turner, and boring, turning, and facing at one chucking. When, too, it is combined with provisions for self-acting sliding, and screw cutting, the gap lathe is a nearly universal machine. The gap doubles the swing of the lathe for face work, and often avoids the need for two chuckings.

The gap breaks the continuity of the girder bed. It involves putting the lead screw and back shaft low down, and a bridge piece is required to fill it up when the rest has to be brought close up to face work, or for boring. The principal objection is got over by adding ample metal below, or by bringing the metal down to the floor to form a foot. The others are of little moment. The principal practical objections are that due to the wear of the bed next the gap, arising from the large amount of face work; and the rigidity of the gap, the width of which cannot be lessened or increased.

These objections are nearly absent in the movable or sliding gap lathes, Fig. 67, Plate V., in which the width of the gap is adjustable,—making the lathe bed capable of longitudinal adjustment, by sliding it along a base plate, which forms a continuation of the headstock base. When not required, the gap is closed entirely. They resemble, therefore, the break lathes, but they are lighter, of lower centres, and have beds longer in proportion.

Gas Battery.—A term formerly applied to secondary batteries or accumulators, wherein the process of charging was at a certain stage accompanied by the evolution of hydrogen and oxygen gases. An electrolytic cell is now in commercial use for the production of oxygen and hydrogen gases, which is more correctly described as a gas battery. *See* **Storage Batteries.**

Gas Coke.—*See* **Gas Making.**

Gas Condensers.—These are of two types, atmospheric, and water tube, by means of which illuminating gas is cooled. In the first, the gas passes between annular tubes—a tube within another—surrounded and cooled by the air; in the second, it circulates around nests of tubes through which cold water is circulated with a flow capable of regulation. Tubes may be vertical, or horizontal.

Gas Engine.—The gas engine is a heat engine in which the fuel is directly burned in the working cylinder, and pressure is produced upon the piston by the expansion of the gaseous products of combustion and the air admitted with the gas fuel by the heat of the combustion. The gas being mixed with air burns very rapidly and practically explodes. Of the heat generated, about 30 per cent., in the best engines, is converted into work, and the remainder is more or less evenly divided between the exhaust gases, and the water that is circulated through the jacket which is necessary to prevent overheating of the cylinder.

Owing to the absence of a boiler and the more direct use of the fuel, the heat efficiency of the gas engine is much better than that of steam engines in spite of the water jacket which, though a practical necessity, is not a scientific adjunct of a *heat* engine.

Most gas engines work on the Otto cycle of operations. Gas and air are drawn into the cylinder by one stroke of the piston, are compressed on the return stroke, fired at the dead point, burned and expanded on the next forward or working stroke, and exhausted on the fourth stroke. There is thus one working stroke in four when single acting, and two in four when double acting. In engines on the Clerk cycle, separate air and gas pumps are provided which pump the charges into the cylinder before the working stroke is quite complete, and these drive the exhausted gases before them and out by a port that is uncovered by the piston. Such engines may therefore have a working stroke every revolution, or two such strokes when double acting, but at the expense of the two charging pumps.

The valves of gas engines are of lift or mushroom type for air, gas, and exhaust. Both cylinder and piston, as well as the valve seats of large engines, and the parts about the gland boxes, must be water jacketed. Small engines are usually governed by a hit and miss push piece which opens the gas valve and is controlled by the governor to do so, or to miss it. Larger engines are more usually governed by varying the *amount* of the gas admitted. Compression depends upon the relation of the clearance space to the total cylinder volume. Gases

rich in hydrogen cannot be safely compressed, especially in large engines, to more than about four atmospheres absolute, but "Power Gas," which is chiefly CO with not more than 5 per cent. of hydrogen, will compress to ten atmospheres or more without pre-ignition.

The mean pressure in gas engines is higher than that in steam engines, and it is all got in one cylinder, so that though a steam engine has double or even quadruple the number of working strokes per revolution, and therefore a better mechanical efficiency, yet the difference is minimised by the higher mean pressure and fewer parts. At the same time the high stresses have tended to keep the cylinders smaller and to multiply cylinders for a given power, partially with a view to better turning effort; though it is very usual to have cylinders in tandem, and thus free from this effect when double acting, though they may have secured it if single acting.

The charge in the cylinder is ignited by an electric spark, or by an ignition tube. The electric spark is easily timed by means of a make and break contact revolving with the shaft. The ignition tube is a small tube of special metal, a few inches long, kept to a red heat in an asbestos lined outer tube, through which a gas flame plays. As the charge is compressed in the cylinder, it is forced up the tube and compresses the residual burned gas therein until itself reaches the hot portion and is ignited. Sometimes the charge is only admitted to the tube by a timing valve, which is more certain in action. The earlier gas engines worked without compression, drawing in a charge of gas and air, and igniting it by a flame which was sucked into the cylinder from a burner outside. Small engines still lived after the Otto cycle was brought into use. This cycle was devised by Beau de Rochas, a French engineer, who realised that economy was only to be thus secured. Yet in spite of the undoubted priority of de Rochas, the Otto patent was maintained, and no serious work was done by others until its expiry.

Because of the absorption of heat by the water jacket, it has been suggested by W. H. Booth in the *Electrical Review*, and carried into effect by B. H. Thwaite, that the explosion at the dead point is probably wrong. Such explosion produces heavy pressure on the large crank pin and shaft bearings which are moving at full velocity, at a time when there is no possible turning moment on the crank. The temperature is at a maximum, and much heat goes into the water jackets. The engineers named hold that by greater slowness of ignition the early pressure and temperature are moderated, so there is less friction and less waste of heat to the jackets, and as the later combustion then takes effect behind a moving piston in an expanding space, the heat is more directly converted into work, and a net economy should be effected with less shock and wear. In this way the bad effects of the unscientific jacket are minimised. The idea of delayed ignition was originated by M. Delamare Deboutteville. It is not however generally accepted, because of some thermal loss; and is not adopted by any gas engine makers of note.

All the early gas engines were worked by retort gas, and could only be economical for small users and only then in reduced wages. As engines became more common, the gas producer, of which the Dowson was for long the best known, was brought out, and by this means gas can be made at a cost of about 0·1d. per HP. hour for fuel, or even less than this figure. With producer gas it is necessary to make the gas inlet much larger and the air inlet smaller than when retort gas is employed, because the calorific capacity is but one-fourth. With gas from blast furnaces the calorific capacity is but one-sixth that of retort gas, but the power from the engine may be fully three-fourths, because the nitrogen which comes in with the blast furnace gas does but take the place of some of the surplus air that must be used with the too powerful retort gas. Such a gas as blast furnace gas would fail to ignite, were it not for the compression which more clearly approximates its molecules to those of the oxygen.

It is to blast furnace gas, which is going to waste in such large volumes, that the large gas engine with its perfection of detail really owes its origin, and to these large engines, which must necessarily be costly, we owe it that the double acting systems and the revival of Clerk's cycle have made their way in the endeavour to

Fig. 68.—Crossley Gas Engine.

REFERENCES TO ILLUSTRATIONS.

1. Cylinder water jacket.
2. Breech end.
3. Breech end cover.
4. Admission block.
5. Admission lever.
6. Admission and exhaust cam.
7. Gas block.
8. Gas die.
9. Gas pusher blade.
10. Gas lever.
11. Gas and ignition cam.
12. Gas cock.
13. Gas supply pipe.
14. Air supply pipe.
15. Exhaust box.
16. Exhaust valve spindle.
17. Water inlet to exhaust valve.
18. Water outlet from exhaust valve.
19. Exhaust lever.
20. Exhaust shifting bar for starting.
21. Side shaft bracket on breech end.
22. Double tube ignition block.
23. Ignition pusher rod guide.
24. Ignition tumbler.
25. Main water inlet.
26. Water connection pipe.
27. Main water outlet.
28. Exhaust pipe.
29. Starter block.
30. Liner bolts.
31. Side shaft.
32. Side shaft bracket crankshaft end.
34. Governor shaft.
35. Governor tumbler for starting.
36. Governor spring.
37. Governor track rod.
38. Governor adjustment for speed of engine.
39. Oil gauge for main bearings.
40. Oil splasher guard.
41. Hand turning gear.

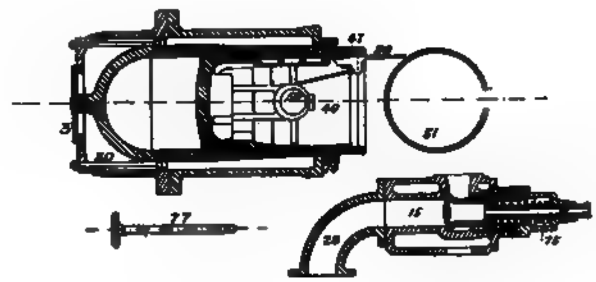


Fig. 69.—Section through Cylinder and Exhaust of Gas Engine.

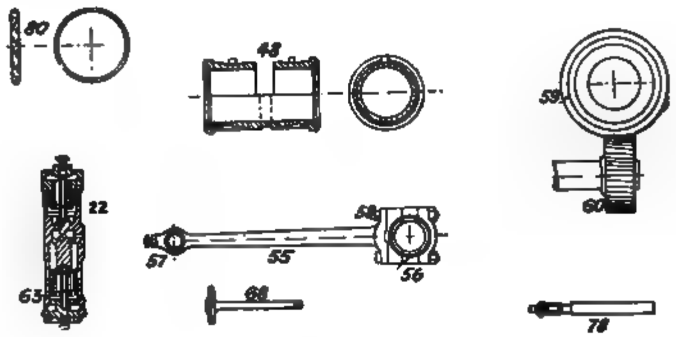


Fig. 70.—Ignition Block, &c., for Gas Engine.

42. Safety catch for turning gear.
43. Air throttle.
44. Piston lubricator.
45. Side frames.
46. Sole plate.
47. Cylinder liner.
48. Main bearing brasses.
49. Piston.
50. Piston pin.
51. Piston ring.
54. Main bearing cap.
55. Connecting rod.
56. Large end connecting rod brasses.
57. Small end connecting rod brasses.
58. Connecting rod bolts.
59. Worm wheel on crankshaft.
60. Worm wheel on side shaft.
61. Worm wheel guard.
63. Porcelain tubes for igniter.
68. Gas valve spindle.
70. Rubber ring for liner joint.
73. Governor sleeve.
74. Governor balls.
75. Exhaust valve spring.
77. Admission valve spindle.
78. Igniter spindle.
79. Water spray for cylinder.
80. Brass ring for self-lubricating main bearings.
99. Piston pin lubricator.

reduce crankshaft stresses, and obtain double and quadruple power from the same weight of engine, or approximately so. This improved design of engine, by introducing better turning moments, has enabled the large gas engine to be used for the driving of alternating current electric generators in parallel, for which regular rotation is necessary. The large gas engine approximates more and more closely to the general form and type of the steam engine, though, as pointed out, it differs in its working, partially because the high temperatures of gaseous combustion are too high for non-jacketed cylinder metal. One brake horse power is claimed to be obtained for as little as $\frac{3}{4}$ lb. of fuel; or to be more exact, a thermal efficiency of the engine of 25 per cent. has been secured; or, say, 1 B.H.P. for each 10,000 B.Th.U. in the gas; and it is claimed that a gas producer will give 90 per cent. efficiency, so that the figure might be obtained. It is better to count upon 1 lb. of fuel per B.H.P. per hour for large engines, but the latest results claim as low as 9,000 B.Th.U. per B.H.P.

The gas engine is the forerunner of other internal combustion engines, the oil engine being most like it (*see* **Oil Engine**), whilst the Diesel engine is a special variety of the oil engine.

The Bucket engine is a form of internal combustion engine, which however employs solid fuel to generate gas to expand and do work.

At the time of writing the gas engine has arrived at a high degree of perfection for stationary purposes, and is coming into the field of practical engineering for marine purposes also. The internal combustion engine cannot be started as such against a resistance, and is not suitable to drive, except through a friction clutch, such things as cars. For marine work, a store of compressed air seems desirable for starting purposes, or some equivalent device. Acetylene gas, C_2H_2, may be used in gas engines of small size, though it is too expensive and probably too powerful for large engines. Indeed it is so rich in hydrogen that it will not bear much compression on this score alone, a failing that is seriously intensified by the endothermic character of the gas. Its calorific capacity is abnormally high from this cause alone, and renders it unstable. For these reasons, coupled with the fact that the small engines for which it is least unsuitable are apt to be in charge of unskilled attendance, acetylene is not to be lightly advocated as a fuel for gas engines. *See* **Diesel Engine, Oil Engine, Petrol Engine**.

Figs. 68, 69, 70 illustrate one of the engines by Crossley Bros., Ltd., of the type which is made by them in four sizes. The reference figures and list of names beneath explain the entire construction clearly.

Fig. 71 shows a 150 B.H.P. horizontal gas engine by the Campbell Gas Engine Co., Ltd. It is fitted with water circulation both to the cylinder, piston, and exhaust valve; also the latter is provided with a balancing arrangement in order to reduce the effort required to open the valve to a minimum, thus saving a considerable amount of wear and tear on the gearing, and rendering the running of the engine more quiet than when this device is not provided. The engine is specially designed for working with producer gas, and is governed on the throttling principle, the quality of the mixture remaining the same through the whole range of its power, the governing being effected by varying the quantity of mixture introduced into the cylinder. Forced lubrication is provided for the cylinder, ring lubrication to the crankshaft and camshaft bearings, and automatic lubrication to the crankpin, to enable it to make continuous runs without stopping.

Fig. 72, Plate V., illustrates a 360 B.H.P. gas engine, running at a speed of 200 revs. per minute. It is coupled direct to a two-phase alternator of 240 kw. capacity. The normal output given is developed when using producer gas having an average heat value of 140 B.Th.U. The maximum B.H.P. is 400. It has four cylinders 19 in. diameter by 21 in. stroke, each cylinder being independent of the others. To prevent bending of the shaft, five bearings are fitted to the crank inside the casing, each of $9\frac{1}{2}$ in. diameter. Electric ignition is employed, each cylinder being fitted with a separate magneto machine. The contact breakers and sparking plugs are in duplicate, and the change from one set to the other can be made while the engine is running. The

Fig. 71.—150 B.H.P. Gas Engine. (Campbell Gas Engine Co., Ltd.)

point of ignition may be varied while the engine is at work. The governing of the engine is effected by a governor of the Hartung type, operating a balanced throttle valve which controls the volume of combustibles according to the load. The governor is driven from the crankshaft, but it is sometimes the practice to drive it from the camshaft. Forced lubrication is a feature of the design, being provided for the cylinders, gudgeon pins, crankpins, main bearings, exhaust camshaft, and exhaust lever.

Gaseous Fuel.—Gaseous fuel has very various properties from the weak gas sent out by the blast furnace to the highly powerful natural gas of Pennsylvania. The best known fuel gases are blast furnace gas, dry producer gas, wet producer gas, water gas, coke oven gas, retort gas, and natural gas. The combustible gases consist of hydrogen, methane, or other hydrocarbons, and carbonic oxide, while the diluents or incombustible elements are carbon dioxide, nitrogen, and sometimes a little oxygen. The annexed Table I. gives the main characteristics of a few of the best known gaseous fuels, while Table II. gives some further characteristics of the separate components.

The earliest of the artificial gases to be used was retort gas, which being distilled in a closed retort is almost wholly combustible, and consists of hydrogen and various volatile hydrocarbons. Such gas when burned gives light because its flame is charged with solid carbon particles. Producer gas (*see* **Gas Producer**) is chiefly half oxidised carbon, and therefore contains fully two-thirds of the calorific capacity of the carbon from which it is made. Water gas is a much more powerful product, and is made by passing steam through red-hot coke, so that in theory it should consist only of hydrogen and carbonic oxide, any other gas being due to imperfect action of the producer. But the decomposition of steam calls for more heat than is given out by the first oxidation of carbon, and the steam will extinguish the hot coke. The water gas process must therefore alternate with a period during which the producer is air-blown to incandescence, the gas being wasted. The wet producer is one which gives more powerful gas than the dry producer, but less so than water gas, and is blown with moistened air so that as a rule it never receives more steam than it can convert. A notable exception occurs in the Mond type of producer, which as usually worked passes a large volume of steam into the producer, of which only about one-fourth is decomposed, and about three-fourths pass out with the gas. Blast furnace gas is merely dry producer gas which, while rendered inferior by the action of the ore and flux used in iron smelting, nevertheless is partially recouped by the great height of the furnace. Coke oven gas is very similar to retort gas.

Upon the percentage of combustible depends the temperature that can be secured, for all other gases or diluents only serve to reduce the temperature. For welding purposes water gas is employed. For gas engines the poorest gas with little hydrogen will burn freely, and will bear the highest compression, and give economical results; for gases with much hydrogen in their composition cannot be highly compressed without risk of pre-ignition, and are even dangerous in large engines.

The advantages of gaseous fuel are that it may be burned with a minimum of air, and the air may be regulated to give either a reducing or an oxidising flame, and the flame may be applied when wanted, and all fuel consumption may cease as soon as work is complete. There is no ash or dirt. Acetylene gas, C_2H_2, has been lately applied to welding purposes by means of a blow-pipe and compressed oxygen; and very high temperature effects are secured.

In order to find the nominal temperature of combustion of a gas, its calorific value per unit is to be found, and this must be divided between the whole of the products of combustion and the diluents. Thus, to suppose a simple case of a gas with 5 per cent. of hydrogen and 25 per cent. of carbonic oxide, 5 per cent. of carbonic acid, and 65 per cent. of nitrogen, the calorific value per pound would be

$$\frac{5 \times 52290 + 25 \times 4383}{100} = 3710 \text{ B.Th.U.}$$

Now the ultimate gaseous product will be—0·45 lb. of steam, 0·393 lb. of CO_2, 0·05 lb. of CO_2, 0·65 lb. of nitrogen, and 1·813 of nitrogen, or a total of 3·356.

The weight of each gas is now multiplied by

the specific heat so as to obtain the equivalent weight of gas of specific heat = unity. Thus—

$$\begin{aligned} &\text{Steam}, && 0{\cdot}45 \times {\cdot}48 = 0{\cdot}216 \\ &CO_2, && 0{\cdot}443 \times {\cdot}217 = 0{\cdot}096 \\ &N, && 2{\cdot}463 \times {\cdot}244 = 0{\cdot}601 \\ &&& \overline{0{\cdot}913} \end{aligned}$$

The result is a weight of 0·913 lb. of specific heat unity equivalent. The total calorific effect is 3,710 B.Th.U., whence is found the temperature $3{,}710 \div 0{\cdot}913 = 4{,}063°$ Fahr. Obviously, since only three-tenths of the original gas was combustible, and there was so much diluent nitrogen, the final temperature is necessarily low. For the highest temperatures, undiluted gases must be used with oxygen, so that the final result may also be undiluted by the nitrogen of the air used.

It is often convenient to work with gases by the cubic foot, since analyses are taken volumetrically, and must be reduced otherwise to equivalent percentage of weights. This is exemplified in the above calculation of temperature, where 5 per cent. by weight of hydrogen has been assumed. This percentage by volume would better fit the other gas ratios. The calculation by volume is simpler also when calculating oxygen volumes, while the N is easily obtained as practically three and one-third times the oxygen.

The heat value of hydrogen in Table II. is given as a high and a low value, the lower value allowing for the latent heat absorbed by the steam formed.

TABLE I.—CHARACTERISTICS OF GASEOUS FUELS.

Constituent.	Blast Furnace Gas.	Dry Producer Gas.	Wet Producer Gas.	Mond Gas.	Water Gas.	Coke Oven Gas.	Retort Gas, Manchester.	Natural Gas, Pittsburgh.	Average Retort Gas.
Hydrogen	2·33	5·30	22·60	28·50	49·50	53·00	45·58	22·00	46·40
Methane	0·75	3·00	4·00 (Methane and heavy hydrocarbons)	2·10	1·05	34·50	34·90	67·00	41·50 (Methane and heavy hydrocarbons)
Heavy hydrocarbons	...	0·20		...	...	...	6·46	6·00	
Carbonic oxide	24·75	20·00	25·20	11·50	35·93	8·20	6·64	0·60	6·70
Oxygen	...	0·40	...	...	...	...	0·29	0·80	...
Carbon dioxide	5·75	3·60	4·20	15·00	4·25	2·00	3·67	0·60	2·10
Nitrogen	66·42	67·50	44·00	42·90	8·75	4·90	2·46	3·00	3·00
Total	100·00	100·00	100·00	100·00	100·00	102·60	100·00	100·00	99·70
Per cent. combustible	27·83	28·50	51·80	42·10	86·48	95·70	93·58	95·60	94 60
B.Th.U. per cub. ft.	97·8	118·00	150·00	154·00	295·00	540·00	...	892·00	600 to 640

TABLE II.—CHARACTERISTICS OF COMPONENTS OF GASEOUS FUELS.

	Symbol.	Density.	Specific Heat.	Lb. per Ft.³	Ft.³ per Lb.	B.Th.U. per Lb.	B.Th.U. per Ft.³	Oxygen to burn 1 Lb.	Oxygen to burn 1 Ft.³	Result of burning 1 volume.
Hydrogen	H	1	3·41	·00559	178·83	52,390 L 62,100 H	293 347	8·00	0·50	1 vol. H_2O
Carbon monoxide	CO	14	0·245	·07817	12·80	4,383	341	0·571	0·50	1 vol. CO_2
Methane	CH_4	8	0·593	·04466	22·391	24,017	1,073	4·00	2·00	2 vols. CO_2 4 ,, H_2O
Acetylene	C_2H_2	13	0·373	·07267	13·456	21,856	1,624	3·077	2·50	4 ,, CO_2 2 ,, H_2O
Ethane	O_2H_6	15	...	·08565	11·95	22,338	1,912	3·733	3·50	4 ,, CO_2 6 ,, H_2O
Ethylene	C_2H_4	14	0·404	·07814	12·797	21,927	1,744	3·428	3·00	4 ,, CO_2 4 ,, H_2O
Oxygen	O	16	0·217	·08926	11·203	(7,762)	(693)	...	...	...
Nitrogen	N	14	0·244	·07845	12·763	...	...	...	...	...
Carbonic acid	CO_2	22	0·216	·12344	8·147	...	...	...	..	...
Steam	H_2O	9	0·48	·05002	19·912	...	...	...	...	...

This correction should properly be made for the hydrogen compound gases also. Though oxygen is only supposed to be a supporter of combustion, it may be assumed as a fuel which burns with all other substances, and produces 7,762 B.Th.U. per pound, or 693 B.Th.U. for each cubic foot of oxygen required to burn any fuel. Any gas which does not produce this much heat per unit of oxygen consumed differs because of endo- or exothermic effects. The figures are calculated from the value of hydrogen's calorific power, and agree for CO, but not for the hydrocarbons, which are complex gases with complex actions during production and burning.

Gases.—The characteristic property of gases is their compressibility and expansibility. The steam engine is a complicated mechanism for utilising this quality in the case of steam in the cylinder. Three factors enter into the consideration of this property—volume, pressure, and temperature. The relation between the first two is conveniently determined by subjecting a certain volume of air to the pressure of increasing quantities of mercury. This is done by means of a long tube bent round to somewhat resemble a hook—the short branch being closed. As mercury is poured down the long branch the volume of the air confined in the short branch is decreased, and careful calculation reveals the fact that the volume of air varies inversely as the pressure of mercury, *i.e.*, if V represents volume, and P pressure, their product $V \times P = a$ constant. With double the pressure the volume is halved, with five times the pressure the volume is one-fifth, and so on. This law (which is known as Boyle's Law) may be stated:—The volume of a gas varies inversely as the pressure, when temperature is constant.

The truth of this law is not affected by a mixture of several gases which do not act chemically on one another. Each gas exerts its own pressure independently of the presence of the others, so that the total pressure is the sum of the pressures due to each gas. This, known as Dalton's Law, governs the behaviour of the mixture of air and water vapour in the condensing engine.

The relations between volume and pressure can be graphically represented on squared paper, a horizontal line being suitably divided to show volumes, and a vertical line to show pressures. The curved line then traced tells the whole story.

In engineering, the condition in Boyle's Law as to the constancy of temperature cannot be said to obtain. Increase of pressure on a gas is followed by a rise in temperature and consequent expansion, so that where the heat cannot escape, the volume for a definite pressure is actually greater than that followed by Boyle's Law. The curve traced on an indicator diagram when temperature is constant is an isothermal one; that under varying temperature is an **Adiabatic Curve.**

All gases, unlike solids and liquids, expand uniformly for equal increments of temperature. Experiment has shown that a gas expands $\frac{1}{273}$ of its volume at 0° Cent. for each increase in temperature of 1° Cent. (the Law of Charles). The fraction given above (equal to ·003665) is called the coefficient of expansion for gases. Conversely, if this law holds good, it follows that a gas cooled to $-273°$ would possess no volume whatever. Such a temperature has never yet been reached, and probably never will be. *See* **Absolute Zero.**

During recent years much study has been devoted to the liquefaction of gases, and the researches of Joule and Lord Kelvin have resulted in the liquefaction of what had hitherto proved obstinate gases. No gas can be liquefied by any pressure, however great, above a certain temperature. This, its "critical temperature," varies for each gas. In some cases it may be at the ordinary temperature of the air, in others either above or below that temperature. Ammonia becomes liquid at the ordinary temperature of the air when subjected to a pressure of seven atmospheres; for oxygen the critical temperature is $-119°$, for hydrogen $-238°$, but for carbon dioxide, 31°.

A remarkable property of all gases is their diffusive power. If a vessel containing a light gas such as hydrogen be inverted and placed over another containing a very heavy gas, such as carbon dioxide—mouth to mouth—after a lapse of a short time the two gases will be intimately mixed, the lighter gas having sunk, and the heavier one risen. This diffusion also takes

place when the gases are separated by a membrane. The diffusive power of gases obeys a fixed law, the velocity of diffusion being inversely proportional to the square root of the density. Thus, with air as unity, the density of hydrogen is ·06926; the square root of this number is ·2632, and $\frac{1}{\sqrt{\text{density}}} = 3{\cdot}799$. Experiments by Graham showed that the velocity of diffusion of hydrogen (air = 1) was 3·83. Experiments with other gases also supported the law.

The phenomena of diffusion, expansibility, compressibility, &c., are readily explained by the kinetic theory of gases. This theory attributes to each molecule of a gas the possession of a certain amount of kinetic energy which keeps that molecule perpetually in a state of motion, a movement of translation. Enclosed in a vessel, the molecules continually strike and rebound from the sides, top, and bottom; compressing the gas means that there are still more of these restless molecules striking the boundaries of their prison, and hence greater pressure. Expansion and diffusive power are similarly explained. The connection between this molecular motion and heat is so close that the terms may be considered as interchangeable. Increase of heat means increase of motion among the molecules, while a lowering of temperature implies a decrease in speed. In other words, pressure is greater when temperature is raised, and less when temperature is lowered. Absolute molecular rest would only be reached if the gas could be brought to the absolute zero of temperature.

The practical application of the laws relating to gases is seen in many machines and parts of machines. Pressure gauges enable the elastic force of a gas in a closed vessel to be measured; atmospheric pressure underlies the action of various pumps; compressed air is utilised in pneumatic riveting, and other operations; and the steam in the cylinder of the steam engine provides abstruse problems relating to volume, pressure, and temperature.

Gaseous Steam.— Superheated steam, which has the properties of a perfect gas.

Gas Exhausters.—The Beale exhauster is the type on which most are made. It has been the subject of several patents, 1848, 1866, 1877, and the Beale-Donkin, 1892. It is not necessary to relate the successive improvements by which the excessive friction, and mechanical efficiency of less than 50 per cent. has been increased by from 30 to 40 per cent. The principal improvements lay in the substitution of rapidly revolving guiding rings by a sliding block in the centre of the cylinder. The exhauster is in principle a blower reversed. It may have two, three, or four blades. The two-blade and the four-blade are shown, Figs. 73, 74, and an exhauster direct coupled to a steam engine by the photo, Fig. 75, Plate V.

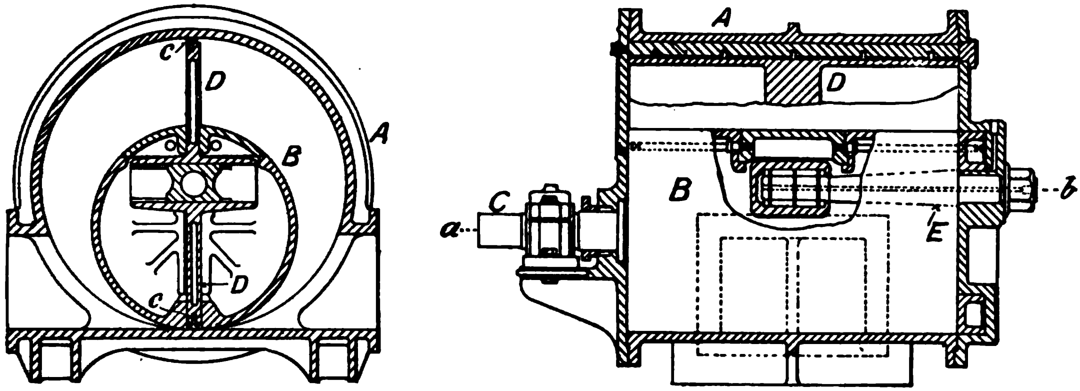


Fig. 73.—Sectional Views of 2-Blade Beale Exhauster. (The Bryan Donkin Co., Ltd.)

The construction of Fig. 73 is as follows:— The gas is exhausted by the action of the rotating axle and blades in the fixed cylinder A, having inlet, and outlet branches. The

axle or drum B is barely in contact with the bottom of the cylinder, and is rotated by the shaft C. As the centre *a* of the shaft C is below the centre *b* of the cylinder, the latter is bored elliptically, its shorter diameter being vertical, and equal to the chord length of the horizontal axis *a*. As the drum B revolves, the blades D are rendered gas-tight by a sliding movement in the body of the axis, and nose pieces or packing pieces *c*, having springs behind, maintain a close fit in the cylinder. The sliding movement is derived first from the guiding pin fixed in the cylinder end, upon which the guiding block rotates, and at the same time coerces the movements of the slides D by the central parallel guides. The end plate which carries the pin E also forms a bearing for the rotating axle B, with provision for lubricating. In the four-blade exhauster, Fig. 74, the slides pass through slotted rollers working in bored recesses in the axle, and the cylinder is bored circularly. The two-blade exhausters have larger wearing surfaces, and should generally be preferred for high pressures and speeds. These are driven by vertical and horizontal steam, or gas engines, or electric motors.

Fig. 75, Plate V., illustrates a gas exhauster coupled direct to a horizontal steam engine on the same bed plate, by which alignment is secured independently of masonry foundations. The fitting of two small heavy flywheels avoids the necessity for making a recess to take one large flywheel, ensures even wear in the crankshaft bearings, and very uniform running at slow speeds. A second exhauster can be added at a later period if required. Variable hand expansion gear is fitted by which the cut-off may be adjusted to the work, with economy of steam when the engine is running with a light load.

Gas Furnaces.—The present tendency is all in favour of the displacement of solid fuel by gaseous fuel, either producer, or waste gas. There are few types of furnaces outside the blast and cupola furnaces in which it is not being successfully applied. Gas is used for open-hearth steel furnaces, worked with regenerators, and for glass melting, for reheating furnaces, for rolling mills, in boiler and plating shops, for angle irons and plates, for foundry stoves, for steam boilers, of egg end, and water tube and other types, and for an infinity of small furnaces used in hardening, tempering, annealing, enamelling, glazing, &c.

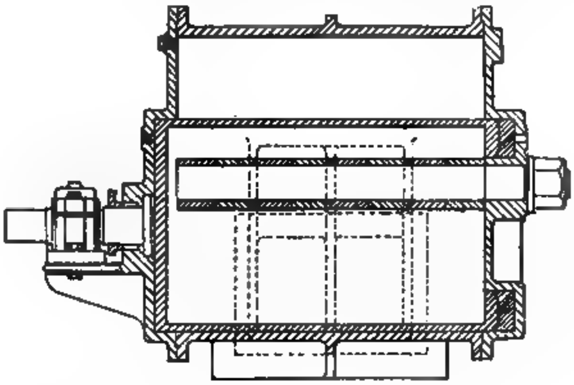


Fig. 74.—Sectional Views of 4-Blade Exhauster. (The Bryan Donkin Co., Ltd.)

Advantages are, the absence of smoke, better regulation of temperature, cleanliness, and the more ready conveyance of gas than of coal. In firing steam boilers with waste gases, the object is not to save fuel, but to utilise gas from puddling furnaces, with the resulting smokelessness and cleanliness. The uninterrupted character of the gas firing has in some cases resulted in an increased evaporative duty. And in the long egg-ended boilers, which are notably subject to great strains consequent on expansion and contraction, the gas is less productive of such evils than coal firing. Gas firing is successfully applied to boilers of the locomotive type fixed in works, and to the Lancashire.

In gas firing a certain proportion of air must be mixed with the gas to produce combustion. When producer gas is used, the calorific energy of which is low, the temperature must be raised by preheating the air for combustion. As there is no limit to the heat which can be obtained in this way, the economies are very high. The essential is therefore the mixing of suitable proportions of air and gas at as high a temperature as is desired. The mixture should be made rapidly and thoroughly. If a high temperature is not required, the air only need be preheated. Producer gas cannot be used properly when both air and gas are cold.

There are two systems of preheating—the continuous, and the reversing regenerators. In the first, the air is drawn or blown through pipes, which are heated by the waste gases circulating outside. These are suitable for the lower temperatures. In the second, the air is heated by being passed through brick-work chequering, previously heated by the escaping gases. The direction of current is reversed at intervals as the heat is abstracted by the cooler air, and when fresh heat has to be given up by the gases escaping from the furnace. There are reversing *gas valves* and *air valves*, set in the course of the passages, and the air and gas are delivered through separate slits on opposite sides of the furnaces, the *gas ports*, and the *air ports* respectively. *See* **Case Hardening, Chequering, Gaseous Fuel, Gas Producer, Regenerative Furnaces.**

Gas Governors.—These are either exhauster governors, or gas station governors. Exhauster governors regulate the suction of the exhauster on the inlet from the condensers. Weights are often used to give any vacuum, or pressure required in the main. Governors are also made to regulate the supply of steam at the throttle valve of the exhauster engine. The general type is a cast-iron tank, containing water in which a floating bell is sealed. The interior of the bell is in connection with the inlet main to the exhauster. There are many variations in detail. The station governor is similar in principle, but it varies the outlet pressure according to the demand for gas.

Gashing.—Roughing out the tooth spaces in machine-cut wheels where more than one cut has to be taken. When a milling cutter is used, it is termed a stocking cutter. Preliminary gashing is usually necessary on wheels above 2 in. pitch.

Gas-Holder.—An inverted cylindrical vessel in which illuminating, and other gas is stored, and sealed by immersion in a tank of water.

Gas-holder designs are suited to the volume of gas required, and there are differences in the method of their construction. They are either single lift; that is, having one cylinder only; or telescopic, having two, three, or more separate cylinders, which slide one within the other. In the telescopic form of gas-holder the inner lifts are provided with annular spaces of U section, or *cups* which retain water at any height of lift by forming a seal within each cylinder. The gas-holder may be counterbalanced or not according to the required pressure.

The tank may be of wrought steel, cast iron, brick, or concrete; the two latter are sunk beneath the surface of the ground. The bottom of the tank need not be horizontal, and in many cases the centre rises several feet according to the diameter of tank, thus avoiding unnecessary excavation, and diminishing the water capacity. The section is therefore approximately conical, or truncated; with a plain slope, or a series of steps. Tanks of wrought steel and cast iron are adopted when the soil is saturated with water, to drain which might cause subsidence of adjacent buildings. These are built of plates, with edges planed and joints well caulked, being wholly or partly above the ground.

The tank is surmounted by a circle of standards. These in the older practice were round cast-iron columns, but now are generally light lattice braced girders of tapering outlines. They carry guides, on which the guide rollers run, and by which the vertical lift of the holders is ensured. In the *balanced lift types*, the tops of the standards carry guide pulleys over which pass the suspension chains, carrying balance weights. The standards are connected with one, two, three, or more tiers of lattice girders, according to the size of the holder, which are further braced together with diagonals, so reducing the tall standards practically to superimposed independent shorter columns.

The gas-holders or *lifts* are built of steel

plates riveted together. The crown is a segment of a sphere of a radius of from about 200 to 300 ft. The thicknesses of the plates are varied according to position. The cylindrical body has vertical stiffeners riveted on, making the shell more rigid. The crown is also trussed.

When a gas-holder is of telescopic type, the lifts fit one within the other, the depth of the inner cylinders being slightly greater than that of the outer. When all are closed, the upper guide rollers each take a bearing one above another on the guides or the standards. But of the lower guide rollers, the ones belonging to the outer lift bear on guides on the inside of the tank, and those of the inner lifts bear on guides on the outer lifts adjacent.

There is a large amount of detail involved in these various fittings. The aim is to make light plated structures of large dimensions as rigid as possible, using stiffeners and gussets, built up of plate, angle, channels, joists, and T sections, with the minimum of cast iron, or cast steel. Specifications are strict and minute in all details, but especially so in the construction of the tank. The quality of concrete, puddle, bricks, stones, and mortar, together with the manner of laying them, and the preparation for their foundations, are minutely specified.

A number of gas-holders have been made without standards or guide framings separate from the lifts. The invention was due to Mr W. Gadd, of Manchester. It consists in encircling the holder with a number of spiral guide rails set at an angle of 45°, and fixed parallel with each other. In some cases they are placed internally. Guide rollers are fixed on the top of the wall of the tank, and on the dips of the lower or outer cylinders in telescopic lifts. These grip the rails in horizontal planes. The result is that the gas-holder moves within the tank in a spiral direction, instead of vertically. The advantages are, a considerable saving in first cost for erection, in weight, and in subsequent annual painting. The removal of the weight of heavy guide carriages from the top curbs permits of lessening of plate thickness there, and lowers the centre of gravity, with less risk of tilting. There is less risk of freezing up. Sometimes a third lift has been added to a gas-holder already built with standards, the addition having been fitted with spirals.

The illustration, Fig. 76, shows half external and half sectional views, both in elevation and in plan, of a gas-holder, made and erected by Clayton, Son, & Co., Ltd.

The photo, Fig. 77, Plate VI., illustrates the largest gas-holder in the world, erected for the South Metropolitan Gas Company, at their East Greenwich works. The holder is 300 ft. diameter, and has six lifts, each 30 ft. deep. The working capacity is 12,158,600 cubic ft.

Gasmaking.—Coal consists partly of carbon, and partly of gases, and of matter that is more or less volatile, and which can be driven off if the coal is subjected to a sufficiently high temperature. The manufacture of gas consists in driving the volatile products away from the carbon, and eliminating from them all substances, such as the tar and ammonia compounds, which tend to lower the illuminating value of the gas, and which are of considerable value as bye-products when properly worked up. The tar compounds, which are extracted from the volatile constituents of the coal, are the foundation of the aniline dyes which are so well known, and which have created such a revolution in the manufacture of dress products. The ammonia when converted into sulphate is a valuable manure. By far the larger portion of the apparatus employed in the gas works is required for extracting the tar, ammonia, carbonic acid, sulphuretted hydrogen, and carbon bi sulphide, which are always present in variable quantities in the gas, and which are so injurious to health when allowed to enter the living rooms where gas is employed for illuminating.

The apparatus at a gas works comprises retorts in which the coal is distilled, a condenser in which the gas is cooled to a certain extent after it has left the retorts, and where some of the tar products are extracted, scrubbers in which the remainder of the tar and ammonia are removed, purifiers in which the carbonic acid, sulphuretted hydrogen, and carbon bi-sulphide are taken out, and the gas-holders.

Retorts.—The retorts in which the coal is heated are now almost universally of iron They are long vessels of various sections, ◠ being a favourite section, while some are circular

PLATE VI.

Fig. 77.—THE LARGEST GAS-HOLDER IN THE WORLD. Capacity, 12,158,600 cub. ft.) (Clayton, Son, & Co., Ltd.)

Fig. 94.—GENERAL JOINER. (Thomas Robinson & Son, Ltd.)

Fig. 97.—40-TON STEAM GOLIATH CRANE, WITH BOILER AND ENGINES ON CRAB. (Ransomes & Rapier, Ltd.)

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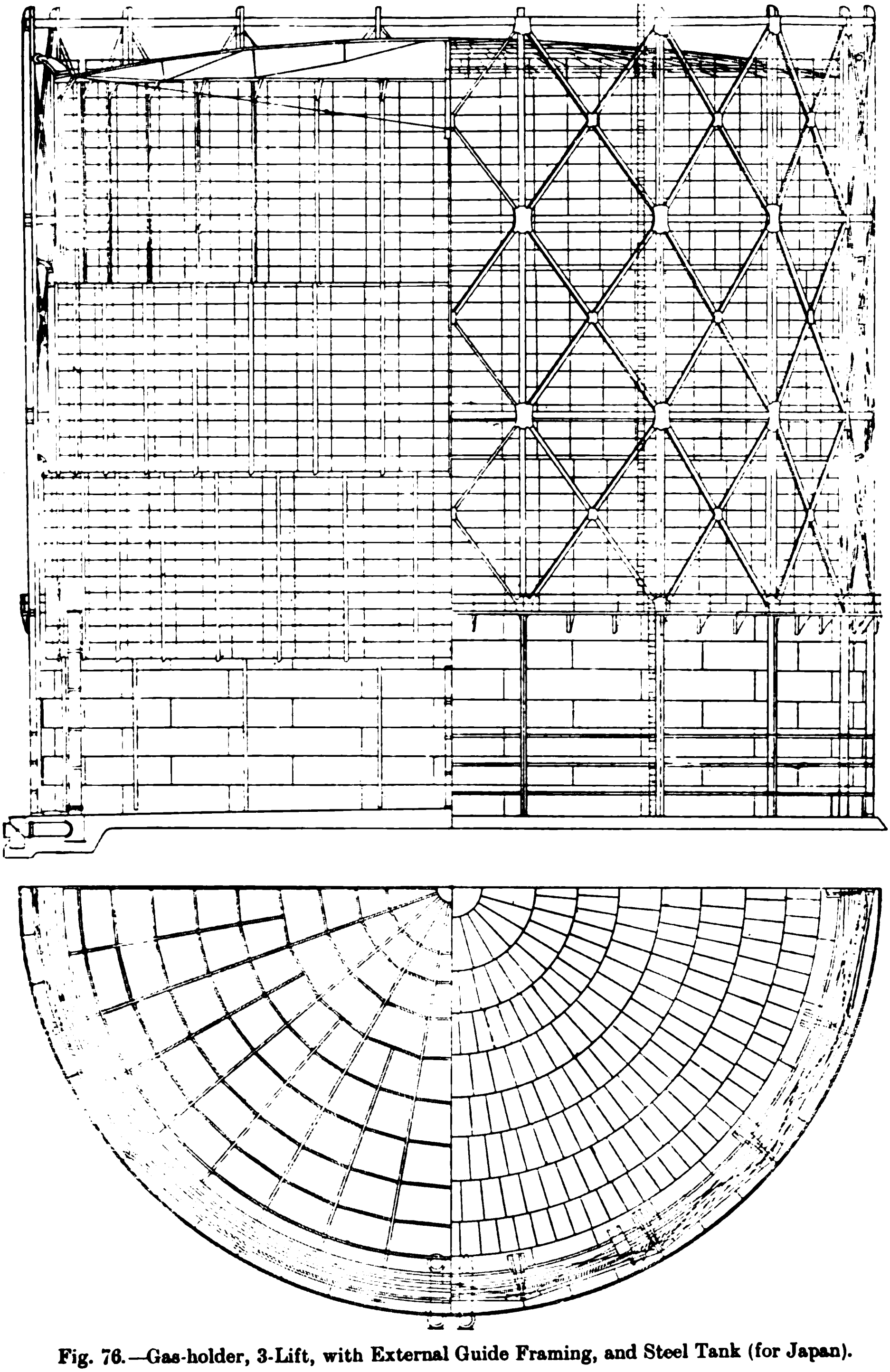


Fig. 76.—Gas-holder, 3-Lift, with External Guide Framing, and Steel Tank (for Japan). Half Sectional and Half External View. (Capacity, 1,000,000 cubic feet.)

and oval. Each retort has a door at one end for the entrance of the coal, and a valve at the other end for controlling the egress of the gas. The retorts are usually fixed in a horizontal position, but they are occasionally inclined. They are heated from outside by furnaces arranged for the purpose, and in the latest modern plant what is termed regenerative setting holds the field. In the regenerative heating arrangement, the retorts are fixed in the setting in such a manner that the air with which the furnace is supplied passes over heated brick or fire-clay surfaces on its way to the furnace, and the whole is arranged so that the utmost possible value, from the point of view of the heating of the retorts, is obtained out of the fuel consumed in the furnace. In some forms of furnace what is practically a gas producer is employed, carbonic oxide being first formed, this being oxidised to carbonic acid within the limits of the heating arrangements for the retort, and a portion of the heat from the gas itself, after it has left the coal, being sometimes made use of to assist the economy. The coke which results is a valuable bye-product.

The Condenser.—The gas, it will be understood, leaves the retorts at a very high temperature. That is the reason why the tar and ammonia products come away with it; and thus practically a large portion of the process of extraction consists in the cooling of the gas below the temperature at which the tarry products can exist as vapour, assisted by the solvent action of water. The condenser consists of a number of pipes fixed usually in a vertical position, the gas passing through the pipes in succession and being cooled either by the passage of a current of air, or a stream of water over the outside of the pipes. The bottom ends of all the pipes are connected with a tank into which the tar falls, as it is separated from the gas by the lowered temperature, and by its own condensation. Before the gas reaches the condenser it passes through what is known as the hydraulic main. The office of the hydraulic main is practically to act as a seal to prevent the egress of the gas into the atmosphere. It consists of a vertical pipe filled with water, and carrying at its top a vessel in which also the water stands at a certain height. The vertical delivery pipe from the gas retorts enters the chamber at the top of the hydraulic main, and is bent over until, when gas is being generated, the mouth of the pipe is below the surface of the water. The pipe from the chamber at the top of the hydraulic main carries the gas away to the condenser. The hydraulic main also serves as a preliminary eliminator of the tarry products, the gas being cooled to a certain extent by passing through the water in the hydraulic main, and a certain portion of the less volatile products being deposited in a tank below. Condensers are of various forms, but all are on the above main lines. In some forms the vertical pipes are annular.

Scrubbers.—The scrubbers consist usually of cylinders arranged vertically, and having in them either loosely packed coke, wooden boards placed on edge, drain pipes fixed in the same way so as to form racks, and, in a late modern form made by Messrs Ashmore, Benson, & Pease, screens formed of wooden frames with canvas stretched over them. In all forms of scrubber the gas from the condenser enters at the bottom and passes out at the top, and there is a stream of water constantly trickling down over the surfaces of the coke, boards, &c. The gas is cooled as it passes over the wetted surface, the tar and ammonia products being condensed in the process of cooling, and being dissolved by the cooling water and carried downwards to a tank arranged to receive them, from which the water with its burden is pumped away to the apparatus designed to convert the tar and ammonia into marketable products. It is usual either to have two scrubbers, the gas passing through them in succession, being led from the top of the first scrubber to the bottom of the second scrubber; or where this is not done, the scrubber itself is divided into two. In either case the first scrubber, or the first half of the single scrubber, is supplied with water partially saturated with ammonia, the second scrubber, or the second half, being supplied with clean water. There are variations of the scrubber known, one form as the rotary washer, and others simply as washers. The rotary washer consists of a drum fixed horizontally, in which the arrangements for extracting the

tar and ammonia are placed. The gas and water circulate through the drum in opposite directions, the drum itself revolving, and it is claimed that the arrangement saves considerable time in the scrubbing process. In another form of washer, invented by Sir George Livesey, a rectangular box is divided into two portions, the upper portion carrying metal plates perforated with fine holes, water passing down through the holes while the gas passes in the opposite direction. There are other forms of washers, and in addition there are apparatus, on somewhat similar lines, for separating the tar from the ammoniacal liquor in which it is held after it has left the scrubber.

Purifiers.—Purifiers are large iron tank-like boxes containing gratings, or sieves, usually of wood, on which are placed substances such as lime, oxide of iron, or manganese, which are designed to absorb the impurities CO_2, H_2S, and CS_2. Lime absorbs the CO_2. Oxide of iron absorbs the H_2S. The box is closed in the majority of cases by a cover with a water seal. The gas is brought into the purifier at the bottom, underneath the trays containing the purifying material. It passes up through the lime or the oxide of iron, leaves behind it in those substances the impurities mentioned, and then passes on to the next purifying box. The purifiers are usually arranged in pairs, the gas in process of preparation passing through one set, while the other set is opened for renewing the material.

Oil Gas.—The best gas coal, Cannel, which is richest in gas, is so expensive that only a small quantity of it is used in modern gas works, the gas being prepared largely from ordinary bituminous coal, and it has become the practice of late to enrich the final product with oil gas. Oil gas is prepared from petroleum oil, in very much the same manner as coal gas up to a certain point. The oil is heated in closed retorts, the heat converting the oil into gas, and the gas is then washed in oil to remove any non-permanent gas, the oil in which the gas is washed being itself employed later on. Oil gas is very rich in carburetted hydrogen, and for this reason it is of great value for enriching the gas prepared from coal, this being comparatively poor in that respect.

Gas Producers.—Gas producers are understood to be of that class which is employed to produce cheap gas for power or for heating purposes. They are known as wet and dry, and as pressure and suction producers, but they are all worked on practically the same principle.

In a dry producer, coke, anthracite, or other suitable fuel is carried on a grate surmounted by a brick-lined cylinder of iron plate, on the top of which is a hopper or fuel feeding box. Air is blown by a fan under the grate, which is also enclosed in the outer casing. It converts the fuel on the grate into CO_2, and heats that above it to an incandescent temperature. The CO_2 which rises through this hot fuel on its way to the outlet pipe absorbs a second atom of carbon, and the result is thus expressed: $CO_2 + C = 2CO$, carbonic oxide being formed. A good deal of heat passes off with the gases. To conserve and utilise this heat a vessel of water is placed at the top of the producer, or water is trickled over the outside of the gas outlet pipe, which is enclosed in a larger air pipe through which air, now mixed with water vapour, is blown or drawn into the ash-pit, and passes to the fuel. The water vapour is decomposed by the red-hot fuel, and the result is carbonic oxide, hydrogen, or methane, CH_4, with less nitrogen than in the dry worked producer. The following are usual analyses of gas from a dry and a wet producer:—

	Dry.	Wet.	Water Gas.
Hydrogen	2·0	12·0	50·0
Carbonic oxide	24·0	27·0	40·0
Carbonic acid	12·0	2·5	4·0
Oxygen	...	0·3	5·0
Nitrogen	60·0	57·0	
Methane	2·0	1·2	1·0
	100·0	100·0	100·0
Per cent. combustible	28·0	40·2	91·0

The hydrogenous gas is more powerful than the dry made gas, but will not permit safely of the same high rates of initial compression, nor is it so safe, especially for large gas engines, but it is useful for heating purposes. No CO_2 is intended to be formed, but some gets through gaps in the fuel unconverted. Nor should

there be any free oxygen in the gases produced. Where the fuel is of considerable depth, the burden in the producer is heavy, and the fuel

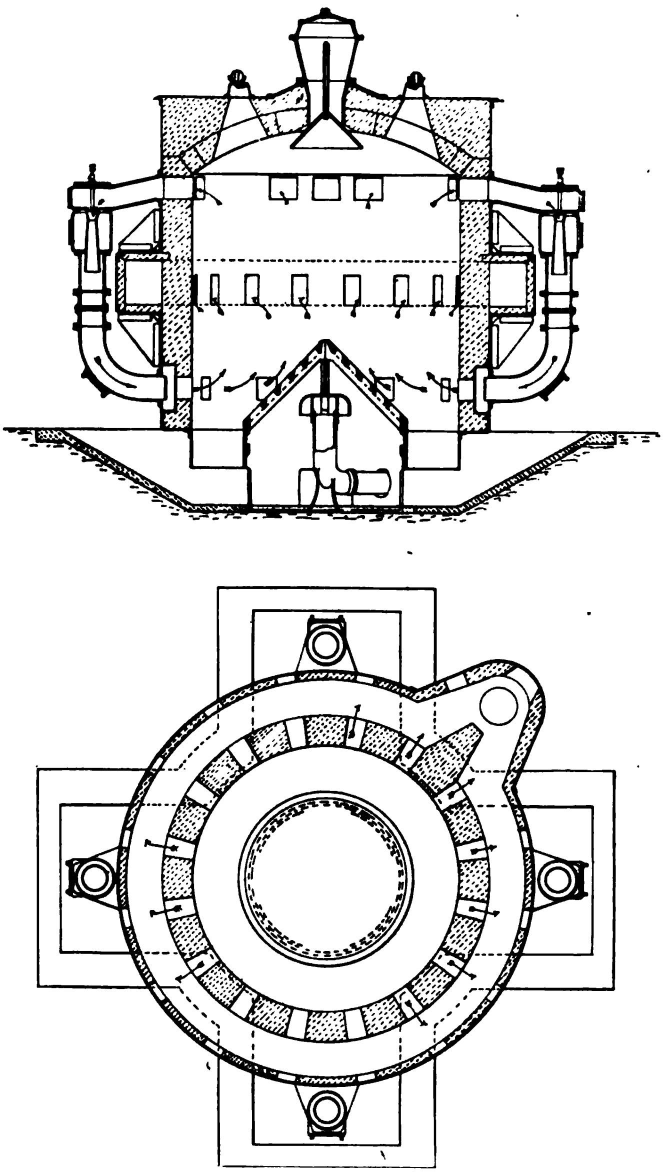


Fig. 78.—Duff-Whitfield Producer.

becomes better consolidated and free from caves, and less CO_2 and O get through unconverted.

In Thwaite's latest type of producer, the fuel has a depth of about 20 feet, and to avoid the necessity and inconvenience of clinkering, there is no grate but merely a hearth as in a blast furnace, and sufficient lime is fed in with the fuel to flux the clinker into slag, which is then run out in liquid form, and may be blown into slag wool. This producer, therefore, stands in a class of its own as regards construction and the method of working, but it can be worked either dry or wet, the wetness, however, being only carried so far as will not interfere with the free fluxing of the incombustible matter. But it is essentially a producer of that ideal gas carbonic oxide (*see* **Gaseous Fuel**) for power purposes, and, owing to the height of the column of fuel, the sensible and waste heat of the gases are low.

Ordinary pressure producers are blown by fan or by steam jet, in which latter case a special boiler is necessary to generate steam at pressure. To this class belong the Dowson, the Wilson, Whitfield-Duff, the Daniels; the jet of steam drawing in air through a form of induced draught injector, and the steam becoming dissociated by the red-hot carbon, and producing CO and H, or CH_4, whereby the percentage of nitrogen is reduced.

To the former type belongs the Thwaite, which is thus able to dispense with a pressure boiler when worked wet, for the fan-blown type may be also worked wet by means of a waste heat water vaporiser. The steam-blown producer is essentially a wet producer. The suction producer may be wet or dry.

To the dry variety belongs the Thwaite, which aims to produce carbonic oxide associated with not more than 3 to 5 per cent. of hydrogen, as originally suggested by B. H. Thwaite and advocated by W. H. Booth for power gas. To the wet

variety belong the Wilson, Pierson, Crossley, Kynoch, Duff & Whitfield, Dowson, Daniels, and others, which aim to produce a gas of 150 B.Th.U. per cubic foot.

Generally a gas producer consists of a vertical brick-lined cylinder with a grate bottom, or, as in the Pierson, a flat plate to carry the fuel, which is open to the air chamber for a short height below the producer, air entering through the wall of fuel and ashes being raked off the plate when necessary for the fuel to be brought down lower. Some producers have a revolving grate or plate, so that by the turn of a handle the ashes are carried from beneath the fuel and swept off the plate by an arm. Into the lower air chamber, air and any steam required is blown or drawn, and passes up through the fuel, which should burn at a rate not much exceeding 10 lb. per square foot of grate per hour for ordinary short producers, with the reactions already stated. The gas passes out at the top, heating a water vaporiser placed round the upper part of the generator if moisture is wanted, or it passes through the ribbed vaporiser already described. The gas then passes to the base of a coke filled scrubber, down which trickles water to arrest dust and acid fumes. Some makers here provide a washer box, after which the gas passes to a sawdust filter, and away to the holder or to the engine. Fuel is fed in at the top of the producer through a hopper with a lowering bell bottom and a close-fitting cover, the bell being lowered, when the cover is closed, by a lever.

In the Duff-Whitfield producer, Fig. 78, the grate is Λ shaped, and rises up in the middle of the fuel, with ash and clinker filling up to the lowest edge of the grate. The producer stands over a water pit into which its casing plate dips to form a seal, ashes being drawn through the water just as in Thwaite's producer, which has a basket grate with a dropping bottom, and provision to carry the fuel on horizontally inserted needles, while the grate is dropped to discharge the ashes intercepted between grate and needles.

To render suction producers satisfactory, Thwaite provides an elastic chamber to moderate and equalise the intermittent pull of the engine. Whitfield gives elasticity by a water chamber. To use bituminous fuel, Thwaite employs a duplex producer with a throw-over valve, which alternates the supply of air to the base of each producer in turn, and simultaneously alternates the draw-off. The two producers have a junction piece at their upper parts and they are fed alternately at the top. The tarry gases thus pass down through the hot and incandescent fuel in one producer, while air

Fig. 79.—Thwaite Gas Producer.

enters at the base of the other and raises its contents to incandescence. Then the flow is reversed and the now hot vessel receives and fixes the tarry gas, and so the cycle alternates. When gas of comparatively high calorific power is required for manufacturing purposes, producers of the Mond or other types are employed in which the fuel is burned by air to a high degree of incandescence, and the gas is sent to waste. Steam is then sent without air through the hot fuel, and the resultant gas is almost wholly combustible and is known as Water Gas.

It is claimed that a producer will make gas which contains 80 per cent. of the calorific value of the fuel fed to it, but there is a loss of latent heat in burning the hydrogen. The Dowson Co. have even claimed 89 per cent. efficiency, and this may be supported by figures and shown to be possible when working is good and the steam supply well proportioned. Except in that of the Thwaite high column type, dry worked producers are not so efficient, but permit of a higher engine efficiency, and in a dye-house are useful for water heating by the waste gases. But even in wet producers not more than 70 to 80 per cent. can be counted upon. The fuel used should be broken to even size, and anthracite is the best, for it does not cake and build into caves and hollows, thereby allowing air and CO_2 to pass upwards unconverted. In the Thwaite producer of blast furnace type the fuel consolidates by its own burden, the blast is strong and the temperature is high at the zone of combustion, and the rate of combustion per square foot of cross section can be high because of the depth of fuel above the horizon of the tuyeres. The gas is purified by scrubbing, washing, and filtration. This producer is *sui generis* and the natural outcome of the discovery that the blast furnace was really an ideal gas producer. All other producers have hitherto been made of small height and differ only in the general arrangement and in details, for they all employ either plain air or moistened air, and act either by blower or suction action, and either continuously or intermittently for water gas; or when for bituminous coal, by duplex action, or by the drawing off of the tarry gas by an inspirator from the zone of distillation, and the forcing of this gas under the grate to be split up and rendered fixed by passing through the zone of incandescent coke or coal.

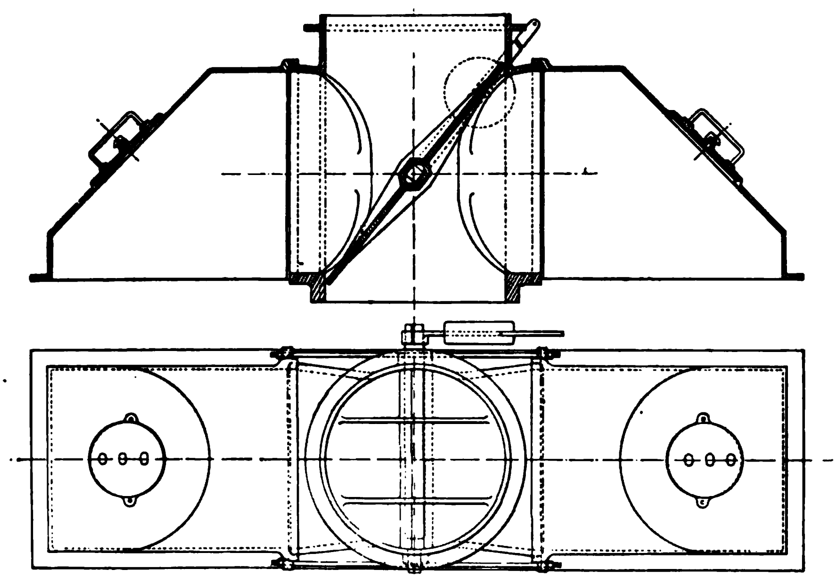


Fig. 80.—36-Inch Gas Reversing Valve.

In Fig. 79 the Thwaite blast producer is shown in section, surmounted with its fuel hopper, which is worked hydraulically from the ground level, and which is fed by an elevator. This represents a single unit of a type capable of generating gas for 1,000 E.H.P. The plant includes a coke scrubber, with bottom discharge valves, an air blast tubular heater, sawdust filter, and holder. *See* **Gaseous Fuel, Mond Gas, Power Gas, Suction Gas Producer.**

Gas Retort Charger. — *See* **Retort Charger.**

Gas Reversing Valve.—Valves for reversing the direction of air and gas in regenerative furnaces, and of illuminating gas in gas works. In the regenerative furnace, the air and gas necessary for combustion are drawn through the heated chequering on their way to the furnace, until they attain a temperature nearly equal to that of the waste gases, which are heating the other set of chequering. When the temperature of the regenerators through which the entering air and gas are passing has been greatly reduced, then the reversing valve changes the direction of the entering and leaving currents, bringing the waste gases through the now cooled chequering, and the air and gas for combustion through the heated chequering. Figs. 80, 81 illustrate valves of this kind.

Fig. 80 is an ordinary 36-inch gas reversing valve, which operates exactly like a common steam throttle valve, closing the passing when at an angle, and fitting in a bored cylinder. The ends of the valves, with the doors covering the manholes are bolted to the seating with socketed joints. The weight of the valve is counterbalanced with a cheese weight on the operating lever.

Fig. 81 gives complete views of a 24-inch gas reversing valve. The valve, counterbalanced, rests on ledges at the sides and ends, and is operated by a lever from outside the gas main. Both of these are by Glenfield & Kennedy, Ltd.

The reversing, or by-pass valves used in gas works are employed for diverting the direction of the flow of gas in connection with purifiers, meters, &c. In some cases they are made to regulate the flow of gas when the governor is not in use. By connecting them up to purifiers, the gas can be passed to any of the purifiers, and any valve box by-passed.

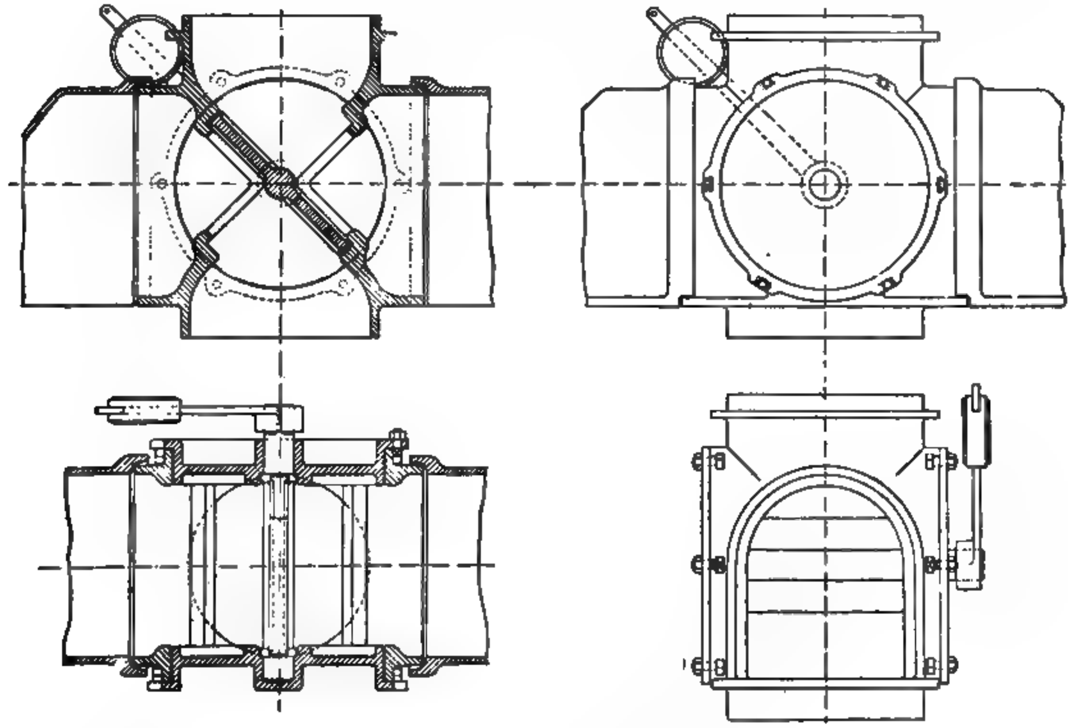


Fig. 81.—24-Inch Gas Reversing Valve.

Gas Threads.—Whitworth fine threads for gas, water, and steam tubes and fittings. There are only four numbers of threads per inch: 28, 19, 14, and 11. The proportions of these threads are given in the table on the next page.

Whitworth's Screw Threads for Gas, Water, and Hydraulic Piping.

Note.—The internal and external diameters of pipes, as given below, are those adopted by the firm of Messrs James Russell & Sons in pipes of their own manufacture, and the pipe trade generally.

Gas and Water Piping.			
Diameter of Piping.		Diameter at Bottom of Thread.	No. of Threads per Inch.
Internal.	External.		
1/8	0·3825	0·3367	28
1/4	0·518	0·4506	19
3/8	0·6563	0·5889	19
1/2	0·8257	0·7342	14
5/8	0·9022	0·8107	14
3/4	1·041	0·9495	14
7/8	1·189	1·0975	14
1	1·309	1·1925	
1 1/8	1·492	1·3755	
1 1/4	1·650	1·5335	
1 3/8	1·745	1·6285	
1 1/2	1·8825	1·7660	
1 5/8	2·021	1·9045	
1 3/4	2·047	1·9305	
1 7/8	2·245	2·1285	
2	2·347	2·2305	
2 1/8	2·467	2·3505	
2 1/4	2·5875	2·4710	11
2 3/8	2·794	2·6775	
2 1/2	3·0013	2·8848	
2 5/8	3·124	3·0075	
2 3/4	3·247	3·1305	
2 7/8	3·367	3·2505	
3	3·485	3·3685	
3 1/4	3·6985	3·5820	
3 1/2	3·912	3·7955	
3 3/4	4·125	4·0090	
4	4·339	4·2225	

Gas Tongs.—*See* **Pipe Tongs.**

Gas Tubes.—Welded tubes, suitable for gas, steam, or water, and made from 1/8 in. to 6 in. internal diameter, with suitable fittings and connections of various kinds. *See* **Tubes.**

Gas Valve, or **Gate Valve.**—A type of valve used for regulating the supply of gas through the mains. It is of the sliding kind, actuated by hand, and having flanged, or socketed, or spigoted, connections for attachment to the pipes. It is made with bores ranging from 2 in. to 48 in., but 24 in. is an ordinary maximum dimension.

The old-fashioned valves were always made with double-acting faces, the vertical section of the valve being that of a wedge of low angle. This effectually closes the passage for a while, but when tarry matters accumulate they form a coating which renders the closing imperfect. The Donkin valves were designed to overcome this objection. In these, Figs. 82, 83, a sliding parallel face is substituted, so that the valve in its downward movement scrapes off any deposit adherent to the face. Tightness is ensured by wedges placed round the circumference of the valve coming into contact with wedges on the valve body, so pressing the faces together. These wedges being small, are not liable to become set fast by the tar, as the wedged-shaped door is. Volute springs fitted behind the door press it down on the faces of the body in its descent, so ensuring the scraping action. Another improvement effected in the Donkin valve is the substitution of a rack and pinion, Fig. 82, for the square threaded screw and nut. The screw, when used, of wrought iron or steel, runs in a nut of gun-metal which fits into the cast-iron valve by tongues. It is liable to corrosion, to stick in the nut, and though the screw is double threaded, the movement of the valve is slow. An alternative to this is a worm operating a spiral rack on the back of the valve in straight-faced valves, Figs. 83, 84. In the spur rack and pinion device, the rack is shrouded, is cast on the back of the door, and the pinion is cut solidly with its spindle. Only one and three-quarter turns of the pinion are required to open any valve.

Modifications in the main type are made to suit circumstances. The screw or the rack may be internal—within the valve body; or outside—in a yoke, or in a column. Indicators, and pressure and vacuum gauges may be included in the column. Valves may be set with the axes vertically, or horizontally. The same type of valves is also employed for water, steam, sewage, and other liquors.

Gates, Gating.—Signifies the channels, and formation of the same by which liquid metal enters a mould after it leaves the pouring basin. Sometimes the vertical passage is termed the *ingate*, and the horizontal the *runners*. *Gits* is a common contraction for *gates*. The metal in the gates is termed the *sprue*. A particular form of runner is a *spray*.

There are no set rules for gating. The general and essential condition is that having regard to the mass of a casting, and the particular metal going into it, the gates must be large enough to fill the mould before the metal can begin to set in the gates, or in its transmission through the thinnest portions of the mould. All the rest is a matter for judgment and experience.

The simplest and commonest form of gate is shown in Fig. 85, A. It is simply a tapered channel formed by ramming up the *runner stick*, or *git stick*, B, in the mould, and withdrawing it, hence the reason for its taper. The pouring basin is formed by hand while the pattern stick remains in the mould. The metal falls directly through the gate into the mould without any change of direction, and this arrangement is suitable for the larger majority of moulds made.

But there are many cases where the fall of metal would be objectionable, or hazardous, as when it might fall on a core, or on a weak section of sand, or might have to take a circuitous route to fill the mould; then it is better to bring the runner in horizontally, C, when it enters also quietly.

The location of the runner is decided by circumstances. Generally it is brought in line with a clear space, as into a rib, or between a mould and core, instead of being allowed to strike full up against a body of sand, whence its direction would have to be changed. Often there is more than one runner entering, one on each side of a core, or opposite adjacent ribs. An extension of this is the practice of using several runners distributed at different parts of a large mould. Thus a mould may be run from opposite ends, or from ends and

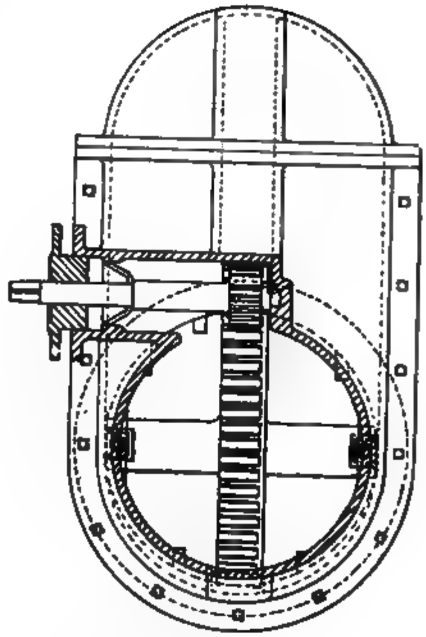


Fig. 82.—Single-Faced Valve, operated by Rack and Pinion. (Bryan Donkin Co., Ltd.)

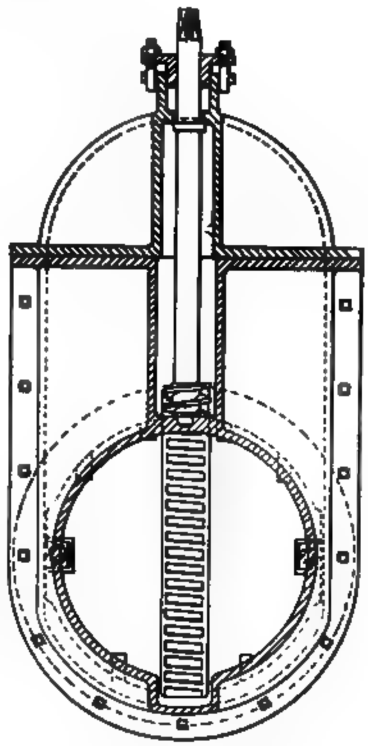


Fig. 83.—Single-Faced Valve, operated by Worm and Rack. (Bryan Donkin Co., Ltd.)

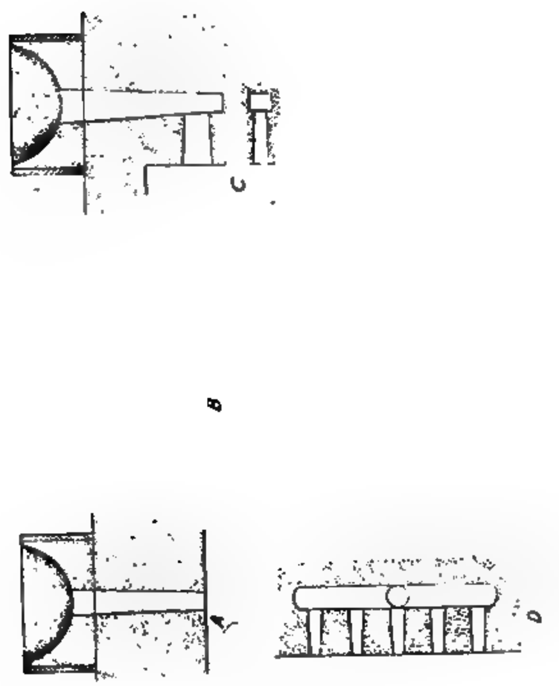


Fig. 85.—Gates.

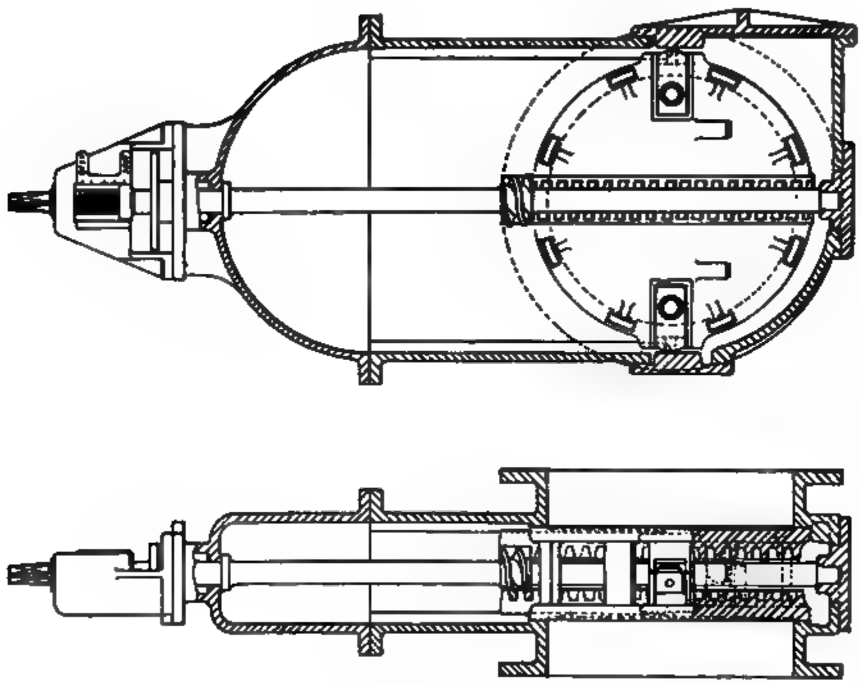


Fig. 84.—Double-Faced Valve, Worm and Rack operated.
(Bryan Donkin Co., Ltd.)

top, or sides, or from sides, and a centre boss; and in other ways to ensure an ample flow of metal to fill the mould.

The same object is sought by using a spray of runners, D, a common practice in moulds where the metal is very thin. A single thick runner might fill the mould just as well, but knocking it off when cold would probably cause local fracture of the casting. Hence the spray of thin runners fills the mould, and is also easily knocked off. There may be two or more such sprays at opposite sides or ends of a casting.

When moulds are very deep they are often poured from the bottom, E. The mould is then filled quietly without cutting up of sand by metal falling from a height of several feet.

The sections of runners are round, and rectangular, more often oblong than square. As it is easier to remove thin runners than thick ones, this is the reason for the oblong section. The extreme is seen in the runners for rain water pipes, which are several inches wide, by only about $\frac{3}{16}$ in. thick.

Runners in hand moulding are cut by the trowel, and smoothed with the fingers, and tools. But in plate, and machine moulding they are included, like pattern parts, on the plates permanently. Much time is thus saved.

Gather, Gathering.—Signifies the increase in thickness of flat or plated portions of moulds, due to the straining and lifting of box parts. Thicknesses of castings will thus often increase by from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. over pattern thicknesses, on large areas. This adds to weight of metal and on cost in large contracts, say for quantities of tank plates. The usual practice, therefore, is to make the patterns under thickness, by the amount that experience shows they may be expected to gather. This thickening is prevented or lessened in various ways. The first essential is stiff and deep top box parts, that will not readily yield to hydrostatic pressure. The next is ample loading about the central areas. Secure cottering or bolting is essential. Also a mould which is poured steadily, with metal not too hot, will be strained less than one poured rapidly with very hot metal.

Gauge, sometimes spelt **Gage.**—This term covers the steam, and water; pressure, and vacuum gauges, described under their heads, which indicate or gauge the pressures or quantities of gases and liquids; and the various workshop appliances of fixed or adjustable character which measure distances on pieces of work. It is not always easy to draw a distinction between calipers and gauges, but the latter are properly of a more fixed type, in some instances having no means of adjustment whatever, a feature which ensures that the dimension measured shall be accurate. In such cases the gauges are constructed either to standard sizes, or to limits above or below standard. For this class of work the ordinary shifting caliper is unsuitable and liable to produce errors; it may, however, be set to a standard when convenient, and employed instead of the latter, a practice which is better than setting by rule divisions. The use of fixed gauges is constantly increasing, as the necessity for greater uniformity and accuracy in work extends, so that instead of fitting two pieces together by machining one to a calipered size, and taking caliper dimensions off this for working the other piece to, both are measured by gauges without reference to each other.

The principal gauges are the **Caliper**, the **Depth**, the **Limit Gauge**, the **Marking**, the **Plug and Ring**, the **Screw Thread**, the **Wire**, described under their respective heads.

Gear Cutting, Gear Cutting Machines.—Toothed gears are cut by two methods, milling and planing, and on many types of machines. An essential in every case is either a division plate, or a dividing wheel, to control the circular movement of the work, and mechanism for feeding up the tool and withdrawing it. In the full automatic machines these operations are effected without the attendant's intervention, but in semi-automatic ones constant attention may be necessary. The difference between planing and milling is largely one of choice, in cutting spur gears and racks; but in bevel gears planing is the only true method, unless extra movements are imparted to the cutter to give the taper of the teeth; while worm wheels can only be cut by rotary cutters. See articles under the heads of **Bevel, Spiral, Spur,** and **Worm** relating to cutting, and machines for cutting.

Geared Machines. — Distinguishes machines which are actuated by toothed wheels

driving to spindles, from those where belt pulleys alone are employed.

Gears, or Toothed Wheels.—The function of these is to transmit circular motion at equal or varying rates of velocity between shafts that are situated not far apart. The perfect or ideal action would be that of a pair of smooth cylinders, Fig. 86, A, rolling by frictional contact alone. But as the power usually required to be transmitted would much more than overcome the force of friction, such a mode of transmission is seldom practicable. Another method is to drive by circumferential grooves of vee section, Fig. 86, B. This affords sufficient frictional contact for

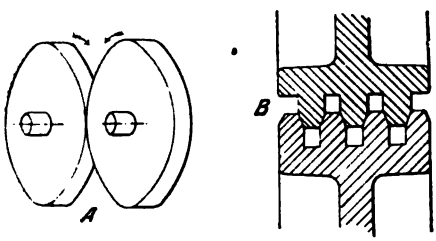


Fig. 86.—Gears.

service in some light mechanisms, and has a limited application accordingly. But in ninety-nine cases out of a hundred the transmission takes place by means of toothed wheels, Fig. 87. That is, projections of certain definite profiles, called *teeth*, are cast upon the rims of the wheels, which by their mutual engagement produce the circular motion required, the effect being largely, though not absolutely identical with that which would be produced by the frictional driving of the peripheries of smooth cylinders.

Definitions.—When the teeth of wheels are set on the outside of a cylinder, and lie straight across, or at right angles, the wheels are *spur* wheels; when they are set on conical surfaces they are *bevel* wheels, in which the teeth regularly diminish in size from their outer to their inner end. When bevel wheels are of equal diameter, the term *mitre* wheels is applied to them, *bevel* being restricted to cases in which one wheel is larger than the other. The term mitre has reference to the angle of 45° which the pitch cones make with the axis of the wheel.

Spur wheels will gear with any other spur wheels of the same pitch of teeth, provided the teeth have been correctly shaped. But bevel and mitre wheels are only adapted to work in pairs. That is, a ten-toothed pinion cannot be substituted for a twelve-toothed one, even though of the same pitch of teeth. But see **Bastard Wheel**.

The terms *wheel* and *pinion* are loosely applied. They are not positive, but relative expressions. When a pair engage the larger of the two is the wheel and the smaller the pinion. *Racks* are straight toothed planes, as though a spur wheel were unrolled and laid out flat. A wheel having teeth on the inner circumference, is termed an *internal* gear. A wheel or pinion having the ends of its teeth flanged is said to be *flanged*, or *shrouded*, or *capped*; and *half*, or *full* shrouded, according as the flange extends to the pitch line only, or to the points.

Screw wheels are those having teeth that form sections of screw threads. *Helical* wheels are a particular form of screw wheels. *Worm* wheels are those in which a screw engages with a wheel having teeth set at the same angle as the worm thread. There are other terms used in the design, and descriptive of the mode of action of wheels, but these are the principal.

Tooth Formation.—The principles of tooth formation, both cycloidal and involute, were correctly laid down in the work of Camus, where they may be consulted now in Hawkins' translation. That work, and Buchanan's, have been sources from which subsequent writers have drawn, and amplified. But in all that concerns expansive practice the present owes little to the past. The proportioning of wheels is better understood now than then. Wheels are built up to be safe at high speeds. Greater precision in the form of teeth is insisted on. Wheel cutting, then nearly unknown in engineers' shops, has attained in some of the best practice a degree of accuracy which leaves little to be desired.

In Fig. 87, *a* is the centre of the *pinion* A; *b* that of the *wheel* B. These are relative terms, always signifying respectively the smaller, and the larger wheels in a pair, or in a series. C is the *pitch circle* of A, D the pitch circle of B. These are the *fundamental*

circles, corresponding with the diameters of the smooth peripheries of ideal wheels, or cylinders. The diameters of these circles alone are considered in proportioning velocity ratios. They are variously called *pitch circles*, *pitch lines*, *pitch diameters*, *pitch surfaces*, and *base circles*. The first three are the terms generally used in the shops. These circles are always in contact (in cycloidal gears) at E, the *pitch point*, which is situated upon the *line of centres*, *a-b*. The pitch point therefore divides the line of centres *a-b* in a position inversely proportional to the rates of revolution of the wheel and pinion. That is, in the figure, if the radius *a*-E of the pinion A, is

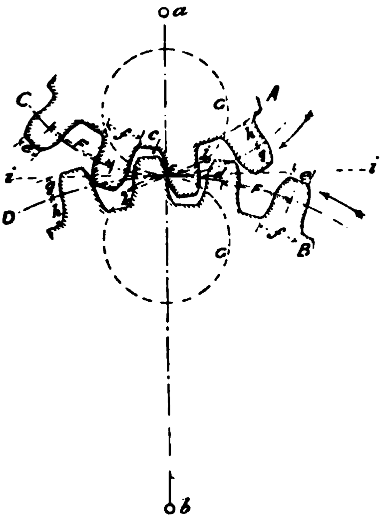


Fig. 87.—Gear Wheel Teeth (Cycloidal).

half the radius *b*-E of the wheel B, the rate of revolution of A will be twice that of B.

Proportions.—It is essential to smooth working, that the teeth on wheel and pinion shall be spaced out equidistantly. The distance F from centre to centre of contiguous teeth is termed the *pitch*, and upon this distance, and the depth of the teeth, or width of face, the strength of the teeth is calculated. For wheels transmitting much power, the pitch is a large dimension, for those doing light work it is a small one. The smaller the pitch, the nearer the mode of action of the wheels approximates to that of ideal cylinders. The shorter the teeth, the stronger they are; each tooth is in effect a short cantilever, and the strength is therefore inversely as the square of the length. But practical considerations require that the teeth shall not be unduly shortened, and the result is that in the evolution of workshop practice, certain proportions are given to the teeth.

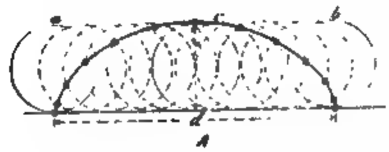
There is a certain amount of clearance, or clear space, both at *c* between the point of one wheel, and the root of its fellow; and at *d* between the flanks of contiguous teeth. These are termed respectively *bottom clearance* (*c*) and *flank clearance* (*d*), and they are necessary to allow freedom of movement between the wheels, and prevent jamming of teeth, and fracture. The more accurately the gears are made the less the amount of clearance necessary.

The width *e* of the point *e*, and the width *f* of the root *f*, are governed entirely by the forms imparted to the tooth profiles, so that they will be wide or narrow with differently designed profiles, as we shall see later. The tooth thickness and tooth space are measured on the pitch line, and do not vary for a given pitch.

Cycloidal Gears.—Fig. 88, A, illustrates the construction of the cycloid. The generating circle in rolling from *a* to *b* develops the cycloid *c*, of length *d*, equal to the circumference of the circle, and of height *e* equal to its diameter. The base circle may be a right line, as at A, or an arc of another circle as at B. From this is derived the practical method of obtaining cycloidal curves for wheel teeth, Fig. 88, C and D, where *a* and *b* represent arcs of the pitch circle of a wheel and pinion for mutual gear. Templets of wood are made, *c*, *d*, to the pitch curves of the wheel; and *e*, *f*, to those of the pinion, against which to roll the generating circle *g* to obtain the curves of faces *h*, *i*, and flanks *j*, *k*. Needle points driven through the generating circle at an angle describe these curves in the act of rolling. The curve *h* will gear correctly with *k*, and *j* with *i*. After these are obtained, the tooth proportions are set out and approximate radii adapted to the curves, or cutters are made approximately or absolutely correct.

Tooth Forms.—In Fig. 87, the two dotted circles G G are the *generating circles*, by means of which the tooth profiles are obtained; and therefore the curves of these teeth are of *cycloidal* form. The pitch circles C D of the

toothed wheels are *base* circles, upon which the generating circles G G are rolled to develop the faces *g*, and flanks *h* of the teeth, extending from pitch line to point, and root respectively in that figure. *g*, *g* being rolled outside the base circles are termed *epi*-cycloids; *h*, *h* rolled within the base circles are termed *hypo*-cycloids. The epi- and hypo-cycloids become what are termed envelopes of each other, and it is demonstrable that when such curves are utilised, the action of the teeth is perfect; in other words, the common normals to these curves at any given point of contact will pass through the pitch point E; and the total action of the gears will in effect be that of smooth peripheries. As the gears are shown in the figure, the common normal is the line *i*-*i*, but at the beginning and end of action, the normals would be along the straight lines *j*-E, E-*k*—still it will be noted—passing through the pitch point E. These normals are the extreme, and middle lines along which the lines of force are transmitted.



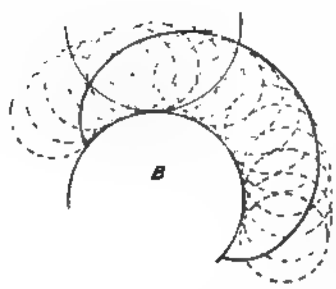


Fig. 88.—Cycloidal Curves.

Path of Contact.—From *j* to E, and from E to *k* there is a double curve coincident with arcs of the circles G G. This represents the path of contact of the teeth which are in mutual gear, and since this path of contact coincides with arcs of the generating circles it is always easy in this type of gear to trace out the mutual action of the teeth. The pinion A, driving as shown by the arrow, contact begins at *j*, where the arc of the generating circle intersects the circle of the tooth points of the wheel; the pinion tooth *flanks* driving first against the wheel tooth *faces*, and the amount of *sliding* of the teeth in a direction transversely to the path of contact is at a maximum. This sliding diminishes until the pitch point E is reached, where it is *nil*, and the action for an instant is that of rolling. Afterwards the pinion tooth face drives the wheel tooth flank, and the sliding action increases again to where the teeth leave contact at *k*. Now both the length *j*-*k* of the arc, or path of contact, and the amount of sliding of the teeth are governed by the diameter of the generating circle G, and this is an essential point to bear in mind when designing gears.

Involutes.—The involute system is illustrated in Fig. 89. In these, A, the *angle of pressure* *a*-*a* usually lies at 75½° with the line of centres *b*-*c* of the wheel and pinion, and 14½° with the right angle thereto. This angle of pressure is constant for all wheels and pinions in an interchangeable system; *d d* are the pitch circles, but these are negligible as far as the generation of the tooth forms is concerned. They coincide only with the relative velocities of the two wheels in gear. The tooth forms are derived from the *base circles e e* which are struck tangentially to the line of pressure; their exact forms may be produced by a tracer point that is attached to the end of a string unwinding from the base circles. This is the basis of the involutes.

To describe them, divide the line of centres, Fig. 89, *b c*, in a ratio corresponding with the ratios of the wheels required. Through this point (the pitch point) draw the oblique line *a a* which represents the path of contact, at the angle considered most suitable, ranging between about $14\frac{1}{2}°$ and 25°, according to the pitch and sizes of wheels. Draw the base circles *e e* touching this oblique line, which therefore becomes a tangent to those circles. On these divide out the teeth equally. Roll a strip of wood having a needle point inserted near one end, Fig. 89, D, projecting just sufficiently to mark a line on the drawing, the strip rolling against the edge of a thin templet cut to the curve of the base circle. Adapt a suitable radius to this curve, and strike out the flanks all round. This method applies identically to both wheel and pinion teeth. Now bisect the distance between flank and flank, and strike two curves—in contact, one of the wheel, and one of the pinion tooth. Comparing now the tooth roots of wheel and pinion, it will be found that a slight difference exists. They should measure the same, so divide the slight difference in width between the two, and then set the width of the roots all round alike in wheel and pinion, and strike the tooth flanks opposite to those which have already been struck, starting from those root divisions. Bottom clearance is given by measurement below the base line.

In shop practice it is generally better to start with the pitch lines, and set the two thicknesses out on those at once, the basis angle having been previously settled by standard gears. And it is interesting to know that the pitch line can be shifted higher or lower, and small gears otherwise impossible be obtained without undercutting of tooth flanks.

In the Brown & Sharpe system, commonly adopted, the teeth are marked as in Fig. 89, B, adapted to any gear of thirty teeth or more. The single curve is an arc of a circle, the radius *r* of which is one-fourth the radius of the pitch circle. The arc *a* is part of a semicircle struck from the centre of the pitch circle, and of diameter equal to the radius of the pitch circle. From the pitch point *b* a distance is laid off to *c* on the semicircle *a*, equal to one-fourth the radius of the pitch circle. The base circle *d* is struck through this, and on it the centres for all the tooth arcs lie.

Rack teeth have straight flanks in this system. As the radius of the rack is infinite, there can be no curvature to the teeth, hence the rack is the basis of the involute. The

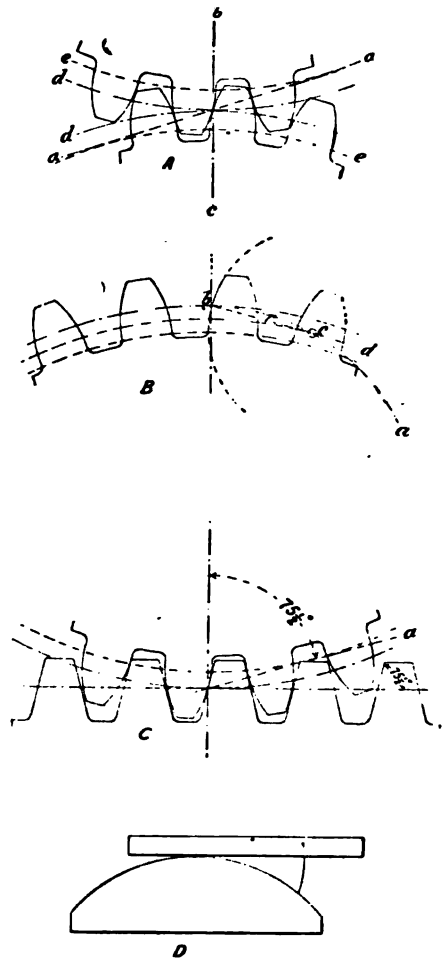


Fig. 89.—Gear Wheel Teeth (Involutes).

relations to the angle of pressure in Fig. 89, C, $75\frac{1}{2}°$, are clear. All wheels designed for that angle and of the same pitch will gear with the rack and with each other.

Cycloidal v. *Involute Teeth.*—It is easy to see now the reason of the difference in the elasticity of the two systems. Dealing with single curves, variations in depth of mesh do not,

flank clearances excepted, affect the smoothness of running. But when two curves start away in opposite directions from the pitch lines, they will foul each other if the pitch lines do not coincide exactly. So close, too, must the curves in the latter approximate to perfect accuracy, that while eight cutters suffice for all involute wheels from a pinion of twelve teeth to a rack, twenty-four cutters are required to cover the same range with cycloids. Also involute cutters can be made to cut deeper or less deep than standard in order to accommodate blanks which are a trifle over or under size, and the results will still be satisfactory. But very little of this can be done with cycloids. In fact, the cutters for these are made with shoulders to prevent them from cutting too deeply.

The involute is therefore a more elastic system than the cycloidal, because the base or generating line is not a hard and fast element like a pitch line, and may or may not coincide with the latter. The practice of cutting instead of casting gears has been very favourable to the involute. It is easier, simpler, and cheaper to cut involutes than cycloids, and bad involutes gear more satisfactorily than bad cycloidal wheels. All present tendencies, therefore, are more in favour of the first named than of the second. Another thing that has favoured the growth of this gear is its association with cal culations based on **Diametral Pitch**. There is no essential connection between the two, since cycloidal teeth are often, in the practice of gear cutting, based on this system. But speaking in a general way, cycloids and circular pitch have gone together, just as involutes and diametral pitch have been linked in practice.

The growth of the involute is one result of the increasing use of wheel-cutting machines of the generating type, because these machines can only be constructed to produce such forms. The reason is that the involute is generated from a constant angle, that of the sides of the rack teeth, and that it is a single curved tooth. Both the angle and the movement through a single arc are easily embodied in machines. Mechanism for generating double curve teeth is impracticable.

Tooth Proportions.—There is no standard yet for the proportions of wheel teeth, which is a matter for regret. Ever since Mr Longridge pointed out the liability of long teeth to fracture the tendency has been to reduce their length. In the practice which was standard for many years, and is still in use by firms whose stock of patterns commits them to a certain practice, the total length of tooth is made equal to twelve-fifteenths of the pitch. At the present time a common rule is—the whole depth of the tooth = ·6866 of the circular pitch. In the diametral system the depth of tooth is made equal to twice the addendum, plus the bottom clearance. The addendum is equal to one diameter pitch, and the bottom clearance equal to one-tenth of the thickness of tooth at pitch line. The flank clearance equals one-fifteenth of the pitch in cast gears, and nothing in cut gears.

Arms.—The arms and bosses of toothed gears are designed as much for convenience of manufacture, and to avoid shrinkage stresses, as from considerations of absolute strength. The

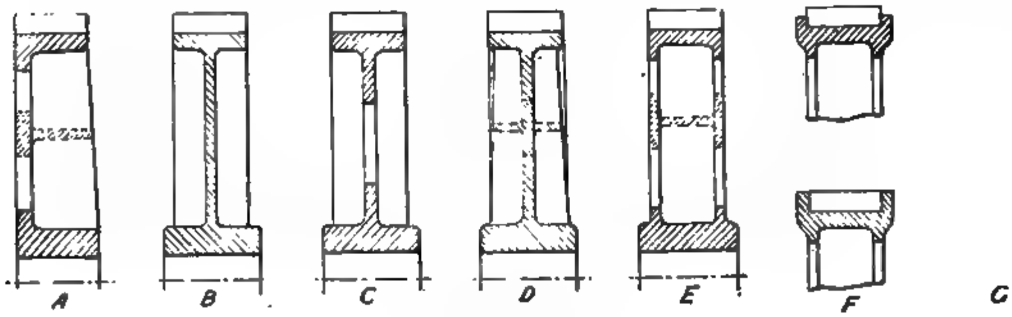


Fig. 90.—Wheel Arms.

⊥ shape, Fig. 90, A, is most common in pattern wheels, the I in machine moulded, E, simply because they are the most easily made. In small wheels the plated centre B is frequently adopted, or lightened out, C. The cross section +, D, is common. In many small machine-cut gears, the arms are of elliptical cross section, G. The shapes of arms often have to be modified to permit of casting wheels together, or for the attachment of wheels to other parts subsequently to casting. Teeth are strengthened by shrouding, F; half as shown above, to the pitch line, or full as below. Many gears have no arms, as when external gears are bolted to crane beds. Large rings are properly made in segments, and bolted to flywheels or other parts.

Materials.—The materials for gears include nearly all the ordinary metals and alloys. Cast iron, forged iron; steel, cast and forged; the bronzes, and brasses, Delta, aluminium alloys, hard wood in mortice wheels, and raw hide.

Cast iron is used to a far greater extent than any other material, being both cheap, and offering no special difficulties in casting. Steel would be used more but for the difficulties arising from shrinkage strains, and draws, which distort castings that are not very equally proportioned. Forged gears are used to a considerable extent where toughness is required. They are machine cut. The tough bronzes, chiefly phosphor bronze, are employed for small pinions gearing with cast steel or iron, in cases where great durability is required, and where the rapid wear of pinions would involve temporary stoppage of machinery for renewals. The raw hide gears have come into extensive use by the growth of the electric drives, being employed for the small pinions on dynamo and motor shafts running at high speeds.

Methods of Manufacture.—Gear wheels are made by casting, and cutting, and occasionally by die-forging, each of which opens up a wide field of detail. Full patterns are used, or segmental parts for moulding by machine. Cutting is done by processes of milling, and of planing. Details will be found in various articles concerning **Bevel Gears, Gear Wheel Moulding Machines, Helical Gears, Spur Gears, Worm Gears,** &c.

Speed of Gears.—The periphery speed of gears measured at the pitch line (the major diameter in bevel wheels) should rarely exceed 3,000 ft. per minute, while 2,000 is an ordinary maximum for cast iron, which may be exceeded for steel. Cut gears run better than cast, and generally machine moulded better than those cast from patterns. Short-toothed wheels are less liable to fracture than those with teeth of ordinary length. The table below gives maximum speeds:—

	Ft. per minute.
Ordinary cast-iron wheels - -	1,800
Helical wheels - - - -	2,400
Mortice wheels - - - -	2,400
Machine-moulded cast-iron wheels	2,000
Machine-moulded steel wheels -	2,500
Machine-cut wheels - - -	3,000

Gear Wheel Moulding Machines.—Machines which are in principle dividing machines, fitted with necessary adjustments for the moulding of the teeth of wheels; arms, &c., being produced apart from the machine by means of cores in the usual manner. The teeth are moulded in green or in dried sand. The chief advantage obtained is the equal pitching of the teeth, and the economy of making a tooth block, core box, and striking boards, against the cost of a complete pattern wheel. But this economy is obviously related to the number of castings required. When a large number of small wheels are required, the cost of a pattern would bear but a small proportion to the expense of moulding in a machine. With large wheels, of which one or two castings only are wanted, the economy is very great. Hence small wheels required in quantity are better made from machine-cut patterns on a common moulding machine, while those of large dimensions go to the wheel moulding machines. Those of medium size go to either, the choice depending chiefly on the numbers required off.

In neither method of moulding is the free rapping that is done on hand-moulded patterns practised. So that there is the further advantage of teeth without enlargement, and teeth without taper. The withdrawal of parallel teeth, ensured by the stripping plate in the common moulding machine, using complete patterns, is provided for by a stripping bit held on the sand in the wheel moulding machine.

The older practice was to employ two teeth only for moulding from. This is still retained. Then one tooth space only is rammed at a time, and the block is moved round a distance equal to the pitch between each ramming. But three teeth or even more are used, and the number ... moves reduced.

...t wheel moulding machine made ...ntion of Mr P. R. Jackson (1855). ...table type, comprising the essential ...he modern machines. Scott's was ...bout 1865, and was a favourite for ... But being a pillar machine, it ...rigidity of machines having the ...fforded by beds and tables. Also ... no provision for moulding wheels ... Every mould had to be made ... the floor, the workman kneeling, ...l as the pillar was 6 in. in dia...ter, no pinion smaller than about ...in. could be made on it. And the ...chine also had to be lifted out of ... step and taken away before a ...uld could be cored up and cast. ...en the machine must either lie idle ...ring the interval, or another step or ...ps be provided in the floor. The table machines are free from these disadvantages, moulds are rammed on the table and removed for coring up. Yet since large wheels are better moulded in the floor, either separate machines are used, or the dividing mechanism is made capable of use on the table, or a floor basis. Of the present types of table machine we select two for description; the Buckley & Taylor, and the Whittaker.

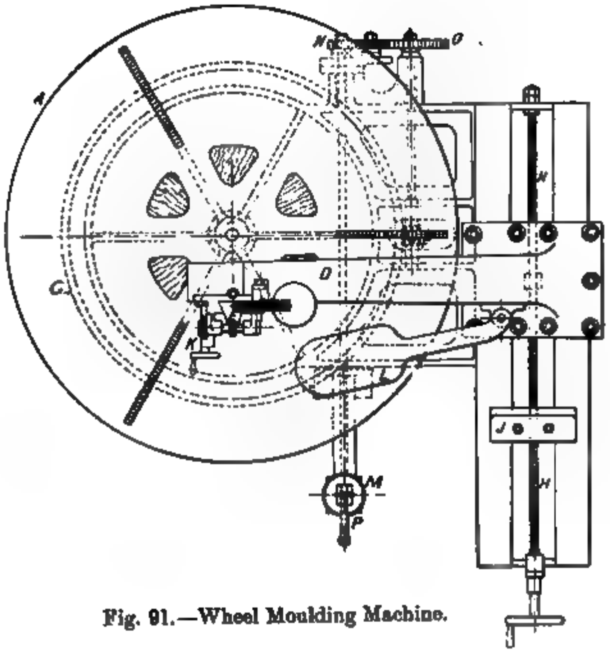


Fig. 91.—Wheel Moulding Machine.

The two Buckley & Taylor machines, the table, and floor, cover a range of gears from 6 in. up to 25 ft. The first named is shown in Fig. 91. The table A is carried on a pivot in the base B, to an extension of which the bed C is bolted. The transverse movement of the arm D along the bed is the means by which adjustment for radius is effected. In the Scott machine this adjustment was made by the radial movement of the arm, which on long radii produced unsteadiness when lifting and lowering. The vertical motions of the slide E lift, and lower the tooth block, at its

lower end, and it is counterbalanced at the other by a suspended weight. The table A is rotated by worm gear F, G; the arm D is traversed by the screw H and handwheel, and clamped by the screws in its base when making vertical lifts. For horizontal withdrawals, as in worm wheels and helical wheels, the stop J is provided to reset the arm by. Worm and spur wheels actuate a rack on the vertical slide E. The

Fig. 92.—Wheel Moulding Machine in Floor.

a sling chain for lifting and lowering the table by. When a small wheel is being moulded, these are filled with blocks of wood, as shown, to give a level face.

The dividing or pitching mechanism which is common to all machines, comprises the worm F and wheel G, the division or notch plate M, having four notches at angles of 90°, the wheel N on the *handle shaft*, and the wheel O on the *worm shaft*; N and O being connected with an idler on a swing plate. The changes are rung on wheels N and O, and compound trains are not used. The notches in the plate M permit of setting the exact number of turns.

If the numbers of teeth on N and O were equal, and one turn given to the handle P around the notch plate, then the wheel being moulded would obviously have the same number of teeth as the worm wheel G, or 180 teeth. For all pitchings, the rule is:—"As the number of teeth in the worm wheel G is to the number of teeth in the wheel to be moulded, so is the number of teeth in the wheel N, required on the handle shaft, to the number of teeth in the wheel O, required on the worm shaft. If the result is in the form of a fraction, multiply it by any convenient number to produce a whole number of teeth, and use the same multiplier for the turns to be given to the handle P in the

; between this and the that the latter has a on a permanent base. e and table from Fig. eives a guide and a justment is made for gth of the slide should be noticed, which prevents all risk of unsteadiness at long radii. Similar reference letters denote identical parts in the two figures.

The machine of Messrs Whittaker is convertible by means of an extension slide to mould wheels ranging from 3 in. to 25 ft. in diameter. The peculiarity of the machine is that the radius is adjusted neither radially nor transversely, but by slewing the pillar that carries the arm, around the axis of a hollow socket within which it fits. This involves a different arrangement of the tooth block carrier from that in any other machine. It is made to swivel around a vertical axis and clamped. Another feature found only in this machine is the capacity for horizontal withdrawal by a movement of a slide on the horizontal arm. It is moved by a screw and handwheel. This is a necessary fitting, because of the radial fitting of the machine, but it is also of much value in helical work, and worm wheels.

In the smaller Whittaker machine the socket is an essential part of the moulding table. But in the larger size it is carried on an extension bed, along which it can be slid and adjusted,

the change gears travelling with it. For wheels of over 8 ft. to 10 ft. the base and the table go in the floor, and the horizontal arm is removed from the top of the pillar, and bolted to the table. In this way provision is made for wheels from 12 ft. to 14 ft. in diameter. For wheels over these sizes the arm is bolted by its flange to a flange on an extension slide, which is bolted to the table. The change wheels are disconnected, and reconnected as required. *See* **Bevel Gears—Machine-Moulded, Spur Gears —Machine-Moulded.**

In reference to the methods of withdrawing blocks, these include vertical, horizontal, and diagonal, or angular lifts. By far the largest numbers are lifted vertically. All spur blocks are lifted thus, so are those for racks. All bevel wheel blocks can be lifted similarly. But those for helical spurs, and bevels, and for worm, and screw or angle wheels cannot be withdrawn bodily upwards. They can be, and are, drawn horizontally bodily. But the method is clumsy, and is rather of the nature of a makeshift, because so heavy a mass must be moved to effect this. In Scott's machine the whole horizontal arm has to be moved. In the table and jib machines the whole jib has to be moved. There are stops used for resetting the block to correct radius, but the method is not satisfactory, being wasteful of time and labour, and liable to cause slight errors. Then there is the desirability of a slide for angular withdrawal, useful in the case of helical bevels. Generally, therefore, a convenient compromise is effected by dividing the tooth block itself in such fashion that a portion is withdrawn vertically by the machine slide, and a portion or portions are withdrawn subsequently by the hand, in a horizontal, or diagonal direction, as is convenient. The portion lifted vertically forms no portion of the actual wheel, being a backing or support only for the teeth, the portions withdrawn subsequently are the teeth themselves. There are many ways of jointing adopted. *See* **Helical Gears.**

In order to avoid the necessity for jointing blocks in this way, which is, however, often convenient for other reasons than that of facilitating withdrawal, Messrs Buckley & Taylor's special carrier was designed. This permits of the withdrawal of a block either horizontally, or at any angle. It is bolted to the machine slide by a piece which terminates at the bottom in a disc with curved slots, on which the plate, with vee'd edges can be set, and tightened at any angle. The slide is fitted to this with a setting-up strip, and is traversed along it by means of a hand-wheel and screw. The carrier is hinged, so that it can be set and tightened in any position.

Gear Wheels—Strength of.—The strength of wheels is estimated by two methods—one as that necessary to sustain a dead load, the other as that required to transmit a definite amount of work, as HP. In the first case speed is not estimated, in the latter it becomes a vital element in the calculation. If a wheel is revolving very slowly, dead load alone need be considered. If a wheel is revolving rapidly, the HP. transmitted is, as in the case of rapidly moving bodies, the convenient unit of work on which to base calculations.

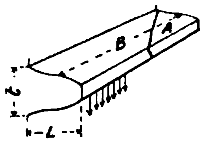


Fig. 93.—Tooth Loaded as a Beam.

If the strength of teeth is estimated to resist a dead load simply, they are regarded as cantilevers, or beams, fixed at one end, and loaded at the other, Fig. 93. The strength of such beams varies directly as the breadth B, as the square of the depth or thickness t, and inversely as the length L. Therefore it is to the depth t that increase of strength is chiefly due, and this in wheel teeth equals the thickness of tooth there, and is proportionate to the pitch. The strength mainly increases as the square of the pitch, because L and B are usually made proportionate to the pitch. So, conversely the pitch is proportionate to the square root of the pressure. The formulæ become therefore—

$$(1)\ \frac{t^2 \times B \times M}{L} = W.$$

$$(2)\ \frac{L \times W}{B \times M} = t^2.$$

$$(3)\ \frac{L \times W}{t^2 \times M} = B.$$

W being the breaking load in lb., and M being a constant multiplier representing the unit strength of the material used for the gearing, and being equivalent to the breaking strength in lb. of a cantilever of that material, 1 in. square, and 1 in. long; taken at 6,000 lb. in cast iron.

Since the curvatures of teeth vary much, and as t measured at the root will vary slightly with variations in diameters of the wheels, it is usual in the formulæ to reckon t as being equal to the thickness on the pitch line, because that is then an invariable proportion, ·48, of the pitch; being less than ·5 pitch to allow for flank clearance in cast gears. Also, to make allowance for wear, it is properly taken as less than this, or as suggested by Professor Unwin, ·36 pitch. The pressure is only concentrated on the extreme end of the length L at certain periods, that is as the teeth are entering, and leaving gear. At all other times the stress is less. But in basing the formulæ on the first contingency the position of greatest stress is taken, otherwise the formulæ would not be reliable.

Excessive increase of breadth B may not tend directly to increase of strength. For here the inaccuracy of practice comes into play. The teeth may be and often are not at precise right angles with the wheel faces, or the wheels may not be hung precisely true on their shafts. For these reasons some formulæ assume that the load is concentrated on one corner only of the teeth, tending to break off a triangular prism, as at A, Fig. 93. Wheel teeth do often break in that fashion, showing that the load is concentrated on the corner. But they as often break nearly straight across, in a more or less jagged irregular fashion. Moreover, there is less excuse now for accepting this contingency, because machine-moulded gears are practically free from error; and in pattern gears only those of exceptional width should be very much tapered. Then they can, in many cases at least, be so hung on their shafts that the taper of one is in the reverse direction to that of its fellow. After wheels have become worn a little they come into perfect contact, so that inaccuracy of contact occurs only when they are new, and at maximum strength. When weakened, their contact is absolutely true.

The proportions between the pitch and breadth vary. But B is seldom less than twice the pitch, or more than four times the pitch.

The requirements of modern engineering are too exacting to permit of the indiscriminate use of formulæ such as these just noted. There is a vast deal of difference in the manner in which gears have to be driven. Some are driven slowly and steadily, others in a more irregular fashion, while in other cases very violent shock comes into play, stressing the material in a trying fashion. Formulæ are prepared, therefore, in which these influences are estimated, and embodied. The Unwin formula evolved for the strength of wheel teeth is—

$$p = K\sqrt{\frac{p}{b}}\sqrt{P}$$

where p = pitch,
K = a multiplier,
b = breadth of face,
P = the whole pressure transmitted.

This is a general formula for wheels subject to ordinary shock only, and is therefore applicable to the majority of gears. The multiplier K in this equation is taken at ·0707 for iron wheels, and ·0848 for mortice wheels, and these values correspond with stresses of 4,400 lb. per square inch in iron teeth, and 1,650 lb. per square inch for wooden teeth. $\frac{p}{b}$ denotes the ratio of the pitch to the breadth of wheel face, and introduces a factor not taken account of when the stress is supposed to act only upon one corner of the tooth, or when the face width happens to be less than twice the pitch, which very seldom happens.

A rule taken from a standard American work on gearing which appears to be practically identical with this of Unwin's is as follows:—To determine the pitch for a cast-iron gear; multiply the force to be transmitted by the *ratio* of the pitch to the face width, extract the square root of the product, and multiply the result by ·078 for violent shock, ·07 for moderate shock, or ·05 for little or no shock. The equation for moderate shock therefore stands:—

$$p = \cdot 078\sqrt{p \times \frac{p}{b}}.$$

Having to do with force in rapid motion other conditions come into play. Work increases directly as velocity, so that if the rim of a toothed wheel travels at the rate of 4 ft. in a second that velocity will represent twice the number of units of work which would be done by the same wheel under the same conditions of pressure moving at the rate of 2 ft. per second. Horse power is only a convenient expression to represent 33,000 foot pounds of work per minute. The HP., therefore, of wheels varies directly as their velocity; a wheel moving twice as fast as the same wheel under the same conditions of pressure will develop twice the HP. in the former case as in the latter. But the pressure stress on the teeth varies inversely as the velocity, an important point.

Since a HP. = 33,000 lb. lifted 1 ft. high per minute, we have:—

$$P = \frac{33{,}000\,H}{60v} = \frac{550\ H}{v},$$

where P = total pressure transmitted,
H = HP.,
v = velocity at the circumference of pitch line in feet per second, the latter being the most convenient formula.

The Wilfred Lewis formula for determining the strength of spur gears assumes that the whole load is taken upon one tooth, and considers the tooth loaded as a cantilever. A factor which depends upon the form of the tooth is introduced into the formula; this factor has been determined by the selection of the weakest cross section of involute, cycloidal, and radial flank gears. The factor naturally varies with the number of teeth contained in a wheel. The formula is as follows:—

$$W = spfy.$$

where W = load on tooth in lb.,
s = safe working stress of material,
p = circular pitch,
f = face of gear in inches,
y = factor.

The values of y are given in the following table. The safe working stress s is given below for various speeds, and for cast iron and steel. The horse power transmitted is:—

$\text{HP.} = \frac{Wv}{33000}$ where v = speed of tooth in feet per minute.

WILFRED LEWIS TABLE FOR STRENGTH OF GEARS.

Safe Working Stresses, s, for Different Speeds.

Speed of Teeth	100 or less	200	300	600	900	1,200	1,800	2,400
Cast Iron	8,000	6,000	4,800	4,000	3,000	2,400	2,000	1,700
Steel	20,000	15,000	12,000	10,000	7,500	6,000	5,000	4,300

Factor for Strength, y.

No. of Teeth.	Involute 20° Obliquity.	15° Involute, and Cycloidal.	Radial Flanks.	No. of Teeth.	Involute 20° Obliquity.	15° Involute, and Cycloidal.	Radial Flanks.
12	·078	·067	·052	27	·111	100	·064
13	·083	·070	·053	30	·114	·102	·065
14	·088	·072	·054	34	·118	·104	·066
15	·092	·075	·055	38	·122	·107	·067
16	·094	·077	·056	43	·126	·110	·068
17	·096	·080	·057	50	·130	·112	·069
18	·098	·083	·058	60	·134	·114	·070
19	·100	·087	·059	75	·138	·116	·071
20	·102	·090	·060	100	·142	·118	·072
21	·104	·092	·061	150	·146	·120	·073
23	·106	·094	·062	300	·150	·122	·074
25	·108	·097	·063	Rack	·154	·124	·075

General Joiner, or Universal Joiner.—A combination type of wood-working machine which is specially adapted to the requirements of shops where an extensive plant cannot be laid down. Fig. 94, Plate VI., shows an example which comprises the following:—A circular saw on a rising and falling spindle, to which cutter-blocks for tonguing, grooving, and rebating may be attached. Planing and moulding spindle taking work 12 in. wide by 4 in. thick. Band saw with pulleys 24 in. diameter, sawing up to 9 in. deep. Circular moulding apparatus, with vertical spindle capable of working mouldings up to 4 in. deep. A tenoning apparatus with cutters for cutting complete tenons at one operation. A special table may also be provided for slot-mortising and boring. It will be seen that all the operations in joinery can be done on this machine, with the added convenience that the parts are located close together, so that one man may finish a piece of work rapidly. Alternatively, another helper could be doing some operation, such as band-sawing, as a preliminary to further work. The machine is driven primarily from the pulleys at the end of the frame on the extreme left.

Generating Circle.—*See* **Gears.**

Generating Machines.—*See* **Bevel Gear and Spur Gear Generating Machines.**

Generating Stations.—*See* **Central Stations.**

Geometrical Mean.—The geometrical mean of two quantities is the square root of their product. Thus the geometrical mean of 4 and 9 is 6; for $4 \times 9 = 36$, and $\sqrt{36} = 6$; 9 is as many times greater than ·6 as 6 is greater than 4. Stated generally, $a : m :: m : b$ or $ab = m^2$, where a and b are the two numbers, and m the mean.

Geometrical Progression.—A geometrical progression is a series of numbers increasing or decreasing by a common ratio or constant factor. 1, 3, 9, 27 is an increasing series; 3, $\frac{3}{4}$, $\frac{3}{16}$, $\frac{3}{64}$ a decreasing series. The common ratio (which is found by dividing any term by the one preceding it) is 3 in the first example, and $\frac{1}{4}$ in the second.

Algebraically, a geometrical progression is stated, a, ar, ar^2, ar^3, and so on, where a is the first term and r the common ratio. Since the index of the 3rd term is 2, of the 4th term 3, of the 5th term 4, of the 6th term 5, &c., the index of an indefinite number of terms n, will be $n - 1$; and the nth term will therefore be ar^{n-1}. If z represents the last term, then $z = ar^{n-1}$. The sum of the terms, s, of a geometrical progression is obtained from the formula:—

$$s = \frac{a(r^n - 1)}{r - 1}.$$

German Silver.—Also called nickel silver, is an alloy of copper, zinc, and nickel. The proportions vary, one of the best alloys being produced by 4 parts copper, 2 zinc, and 2 nickel; another alloy is obtained from 6 copper, 3 zinc, and 1 nickel. Spoons and forks, pots, dish covers, and bar fittings are largely made of German silver, its whiteness, and toughness, and the facility with which it takes a polish making it highly valuable for these purposes. It is frequently electroplated, and this is desirable in the case of articles where acids would act on the copper present, and produce verdigris. It is employed extensively in electrical work, for resistance wires.

Gib.—A shouldered strip of metal used as a backing for a cotter, to prevent opening out of a strap by the friction of the cotter. Examples may be noted in Figs. 57 and 58, Vol. IV. The term is also applied to **Adjusting Strips.** A gib-headed key is thus distinguished from one having no head, the gib being required when the key can only be drawn out by its head.

Gimbal Joint.—*See* **Universal Joint.**

Gimlet.—A boring tool for wood, used chiefly for holes for screws. It is not employed in larger sizes than ordinary shell bits, a medium size being $\frac{1}{8}$ in. or $\frac{3}{16}$ in. diameter. Being turned by its handle it does not bore so quickly as a bit operated by a brace, and consequently the latter is always preferred, unless, as is sometimes the case, a gimlet is more convenient. Gimlets are made in twist and in shell form, and less frequently in a combination of the two, and also with a twist like an auger bit, but the most popular form has a comparatively slight twist, and its full diameter is some distance back from the point. In all cases gimlets are provided with screw points.

Girard Turbine.—A wheel of the impulse type, in which the water is under atmospheric

Fig. 95.—Girard Turbine.

pressure only, and has *free deviation*, or freedom to pursue its own course after leaving the guides. The development of this design was due to M. Girard, a French engineer. The ventilation of the buckets was introduced by him, and by preventing the water from filling the buckets, the chance of the wheel working by reaction was avoided. These turbines are made in radial outward flow, inward flow, and axial types. They have the advantage that the high speeds necessary in the reaction types when small quantities of water are available, are not required; but relatively large wheels and moderate rates of revolution are available; for the water can be admitted to all the buckets or to a few only—*partial injection*—without affecting the efficiency. This is a feature of value in cases where the quantity of water varies in different seasons. This turbine is not suited for very low falls, 50 feet being considered the practical minimum for horizontal types, though some with vertical shafts are made for lesser heights.

Turbines with vertical shafts are only used for comparatively low falls, but those with horizontal shafts are suitable for heads up to 1,000 feet. Girard turbines with vertical shafts are seldom made now, being mostly superseded by mixed flow turbines for low and medium falls.

The illustration, Fig. 95, is that of a Girard horizontal shaft, outward flow turbine, by Messrs Carrick & Ritchie, of Edinburgh. Fig. 96 is the 19 inch size in sectional views. The diameter is measured on the inner circumference where the water is received. A indicates the guides or vanes, B the buckets, C is the regulating gate actuated by a rack and pinion D. Fig. 95 shows this turbine connected directly to a dynamo for electric lighting, the lights being run direct from the plant without an accumulator. It is therefore fitted with a governor to control the speed. The water from the main pipe enters the box casting, the inner side of which is closed by a cast-iron lid. The guide ports are formed in the lower part of this box, and the openings are closed by the slide C just now mentioned. The spindle for operating the rack passes out through a stuffing box, and is fitted with a quadrant gearing into a rack which forms an extension of the piston rod of

Fig. 96.—Buckets and Vanes of Girard Turbine. Enlarged View.

the hydraulic cylinder. The supply ports are thus opened one after the other. This makes the partial injection Girard turbine a highly efficient one with diminished water supplies, as the water can be equally distributed into the buckets, and the full efficiency obtained at each stage of the opening.

The wheel is cast with cores, each bucket with a separate core, and all these fitting in a ring print. It is turned all over for perfect balance; the guides, guide ports, or vanes are of gun-metal, as are also the regulating gate and pinion.

Girder.—Generally applied to that form of beam which is of H-section, either rolled, or built up with plate, or lattice braced, or cast, the last-named being seldom used now.

Girder Stays.—*See* **Bridge Stays.**

Girt.—Measurement of timber balks by the circumference.

Git.—*See* **Gates.**

Gland.—A fitting which confines the packing in a stuffing box, and through which a piston rod or pump rod passes. The packing is necessary to prevent the leakage of steam or water, and the gland is essential to retain the packing and compress it as wear takes place. Glands are screwed down with bolts passing through flanged extensions or lugs, or with studs, the nuts of which may be all actuated simultaneously by a gear ring engaging with teeth on the nut peripheries; or in the smallest kinds the glands are simply screwed in, a hexagon being formed for the spanner to take hold of.

Glass Hard.—In the practice of hardening, signifies the hardest grade possible.

Glass-Papering.—Glasspaper is used first for removing the ridges left by cutting tools on wood-work, and after that for rubbing down the roughness between successive coats of paint or varnish. It produces a smooth, but very finely scratched surface, and consequently is seldom used after a final coat of varnish or paint. Glasspaper of coarse or medium grade is employed on bare wood for removing tool marks, and after that a finer grade is preferable. In many cases it is necessary to use only paper that has already had its sharpness removed by previous use. In work where appearance is an important consideration, glass-papering is done only in the same direction as the grain of the wood, but where accuracy of surface and expeditious results are more important, as in pattern-making, the rubbing is generally done first across the grain, and the scratches are afterwards partially removed by finishing with the grain. Care is taken always to use the paper either on a rubber, or in such a way that it will not follow inaccuracies of surface, but will remove the tool marks, and reduce to a uniform level or curve where irregularities in the tooled work exist.

Glasspaper Rubber.—A piece of cork or wood around which glasspaper is wrapped, to enable surfaces to be smoothed more accurately, and tool marks removed more thoroughly, than is possible without the rubber. For flat surfaces the rubber is flat, for curved surfaces it should be curved to the same sweep. Flat rubbers are more frequently required, and they consist of a block, generally of cork, measuring about 5 in. by 3 in. by $1\frac{1}{2}$ in. Cylindrical rubbers are employed, sometimes rotated in the lathe, for finishing round core boxes.

Glazed Pig.—The same as **Blazed Pig.**

Glazing.—Signifies the filling up of the spaces between the cutting particles in a grinding wheel, due to the texture being too close for the work in hand, so that the dulled grains are not removed rapidly enough. A stone or wheel that glazes too rapidly is of an unsuitable grade for its purpose. All wheels, however, require to be turned up at intervals, to expose a clean sharp surface. This is done by means of diamonds for emery wheels and others, or of steel corrugated wheels, or a pointed bar for grindstones.

Glenboig Bricks.—Fire-bricks for steel furnaces. They contain about 63 per cent. of silica, and 32 of alumina, with about 3 per cent. of oxide of iron, and traces only of lime and other alkalies.

Globe Valve.—Derives its name from the globular form of the body, though the valve itself has an annular seating. It is a screw-down valve. It is made in all dimensions and styles, with flanges, sockets, spigots, screwed ends, internal or external; is cast in gun-metal, and in iron with gun-metal fittings, and is too well known to require illustration.

Globoid Gears.—*See* **Worm Gears.**

Glue.—An adhesive substance used by woodworkers. It is generally sold in solid form. It may be obtained either in cakes, or ground, the latter costing slightly more, but being economical owing to the readiness with which small amounts can be dissolved as they are wanted. It is also sold in liquid form, which is more expensive but handy for immediate use, though objectionable for some purposes because of the acid it contains.

Glue is a product obtained by processes which extract the gelatinous substance from the bones, hides, hoofs, &c., of animals. The particles of flesh are removed from these by steeping in lime water for several weeks, and afterwards drying, storing, and thoroughly washing. After being thus purified, the pieces are boiled until tests of the water show that when cooled it solidifies into a jelly. It is then drawn off from the boiler into a tank where it is kept hot sufficiently long for the impurities to sink to the bottom. It is afterwards taken off into coolers and allowed to set into a jelly, and is then sliced up into cakes, and dried till it becomes hard.

Glue Heater.—For heating and keeping glue in a liquid state a double receptacle or pot is necessary, an inner one to contain the glue and an outer one containing hot water. This maintains the glue at a uniform temperature, prevents the pot from getting burnt, and retains the heat for a considerable time when the glue is being used away from the fire, or other source of heat. In shops where a great deal of glue is used, a hot water tank is usually provided to receive several glue pots, so that more than one can be available for use simultaneously; or one that has been away from the heater and become cooled may be returned and a fresh one taken. When also a pot has been emptied and fresh glue has to be melted, that one is generally not available for use for some hours. These tanks contain water heated by the admission of steam. Sometimes they are open at the top, sometimes entirely closed in, with recesses to receive pots. Heating by means of gas burners is also a satisfactory method. Care must be taken to keep plenty of water in the outer receptacle of a glue pot, and also to frequently add water to the glue itself to prevent it from getting too thick. The glue retains its strength better and keeps cleaner if it is covered. Where quantities are used, it is advantageous to keep it hot in a large covered receptacle, and ladle it out into smaller pots as required.

Gluing.—As frequent reheating, or being constantly kept hot, causes glue to give off in vapour some of its adhesive properties, it is best as far as possible to melt only what is required at the time. It should be dissolved slowly, being first placed in the pot with cold water and allowed to soften for a night, or the greater part of a day before heating. The brush should be removed from the pot until the glue is liquid, and a stick of wood used to stir it if necessary. Water is added until the desired consistency is obtained. The water should be clean, and contain no trace of grease of any kind. The parts to be glued should fit each other as perfectly as possible. The glue must be applied hot, and quickly, and the joint immediately closed; superfluous glue pressed or forced out by rubbing the parts together, and then cramps or weights applied to keep them tightly together until the glue has set and hardened, which is not fully accomplished in most cases in less than twenty hours. Nailing or screwing is injurious to a good glue joint, tending to open it in places, and therefore if nails or screws are to be used in addition to glue, the glued joint should be cramped tightly together before they are inserted. A joint in which there is any appreciable thickness of glue is not strongly united. Plenty of glue should be applied to both pieces of wood, but they must be brought into absolute contact, the glue merely wetting the surfaces and being absorbed into the fibres. Glue can only be used satisfactorily for uniting pieces with or along the grain, and not for end grain or crossed grain.

Glut, Glut Welding.—*See* **Angle Iron Work, Welding.**

Glycerine.—Chemically, glycerine, glycerol, or propenyl alcohol is a trihydric alcohol, $C_3H_5(OH)_3$. It is present in the majority of oils and fats, and is formed by fermentation and saponification. Glycerine is a colourless and syrupy liquid with a sweet taste; sp. gr. 1·26.

Commercially, glycerine is a very valuable product. In addition to varied uses in numerous trades, it enters into the composition of nitro-glycerine, and so forms the basis of many explosives; is invaluable as a lubricating agent; and when mixed with pipeclay for the fashioning of models of ornamental castings, glycerine restrains the setting of the clay. It is also added to water used in hydraulic machines to prevent freezing.

Gold Mining and **Gold Extraction.**—Gold is found nearly always in the metallic state, in a few cases combined with tellurium, or bismuth, though a good deal of the gold ore is held with sulphides of other metals. The deposits may be divided into two main forms, alluvial and quartz, the former being the deposits in the gravels of river-beds, and the latter, the formations enclosed more or less in masses of rock.

Alluvial mining is comparatively easy, though not always cheap. Where the deposit is in an old river-bed, the gravel is sometimes taken up with a shovel and washed, the gold remaining behind. Where the deposit is at the bottom of a flowing river, the river itself sometimes has its course altered, so that the gravel may be exposed, and it is then dealt with as in the old river-bed. In flowing rivers also dredgers are sometimes employed, very similar to the dredgers we see in the harbours and rivers round the English coast, with the difference that the dredger vessel carries a washing plant, the gravel being washed after it is brought to the surface, the refuse being returned to the river. Alluvial mining is often carried on by what is termed "hydraulicking," or hydraulic mining. In one form of this a large body of water is held in a reservoir above the deposit, and is suddenly discharged over the gravel, the force of the water carrying the gravel away, and leaving the gold or a certain proportion of it behind. In another method, a jet of water is made to play upon the gravel in such a manner that the whole is carried away with the stream of water, the gold being caught by troughs arranged for the purpose, in which mercury is placed.

Quartz mining is much more expensive, as a rule, and more difficult. The gold and the sulphides of other metals with it is held in the pores of rocks, or in the strata which bind the rocks together, and the process of mining consists in separating the gold-bearing rock from its surroundings, bringing it to the surface, and treating it as will be described. Quartz lies very largely in veins, fissures, or similar deposits, which lie generally at an angle with the vertical, and extend from the surface down to considerable depths. For mining, shafts are sunk either in the vein itself, and at the angle at which it lies, or vertically for a certain distance, then following the dip of the lode. Modern mining favours vertical shafts which strike the lode at a certain depth, but earlier mining was done with shafts at the inclination of the lode. In either case, levels are run out to and in the lode, from the shaft, and the gold-bearing rock is worked by their aid, assisted by what are called winzes, raises, and stopes, the whole of the rock from which it is hoped that gold may be obtained being brought to the surface. The rock is broken away from the neighbouring rocks by blasting. Holes are drilled either by hand power, two men working together—one holding the drill, and the other wielding a sledge hammer—or by means of drilling machines worked by compressed air, the drills being of the percussion type. An explosive is placed in each hole and fired, the rock is brought down, filled into "skips" which run along the levels to the shaft, and is hoisted to the surface.

Treating the Ore at the Surface.—When arrived at the surface, the ore is first usually broken up by machines into pieces of a size that can conveniently be fed to the stamps. These machines are known as stone breakers, and consist of some forms of movable jaws, which close on the rock to be crushed, breaking it to the required size. The rock then passes to the stamps. These are actually what their name implies, they stamp the ore which is placed in them to powder. They consist of heavy masses of iron arranged to be lifted vertically, and dropped, a certain number of times a minute, the lifting being performed by an engine, electric motor, or other suitable power, operating a shaft, carrying a number of cams which engage with tappets on the stem of the stamp, raising the stamp and releasing it

at a certain point of the revolution, the stamp falling by gravity. The stamps work in shoes, or mortar boxes, in which the ore to be crushed is placed, the fine dust formed passing out through screens arranged for the purpose to the amalgamating tables, described under **Amalgamation for Gold and Silver,** and thence to the concentrating machinery. Crushing rolls and ball mills are sometimes employed in place of stamps.

The concentrating machinery consists of, first, classifying apparatus, which sorts the ores out, where, as so often happens, there are other than gold ores present, the classifying apparatus consisting of screens of various forms, some circular and revolving, some flat. From the classifying machines the ore passes to what are called "jiggers," which separate the ore from the gangue, or waste rock. These consist of apparatus in which the fact that bodies of different specific gravity fall through water at a different rate, is taken advantage of, the ore being kept in motion in the presence of a stream of water, the gold separating out. The water which has been employed to separate the ore from the gangue is carried on with its burden to the concentrating machinery. These consist of various appliances known as "buddles," "vanners," &c., in which the forces of gravity, cohesion, and centrifugal force are employed to separate the gold from the sand and other matter with which it is mixed. In buddles, the *slimes*, as the proceeds of the stamps are called, are subject to centrifugal action, the mixture passing outwards over inclined metal plates arranged for the purpose, some of the gold being left on the metal plates, and the dross being carried off to the circumference. In the vanners endless rubber belts are employed, the apparatus being a development of an earlier form in which canvas belts were used. The belt dips into a tank under the apparatus, and is inclined slightly with the horizontal. The slimes are delivered on to the belt, being spread out over its width by a stream of water, which carries it forwards. The bulk of the matter is carried down over the surface of the belt and away, that which adheres to the belt is carried up to a row of water jets near the top, which separate the sandy particles still remaining, driving them down the belt, and allow the gold to be carried forward and deposited in the tank below. The whole apparatus is given a shaking motion which aids the separation of the gold from the other matter. Vanners or concentrators differ in form, and in the methods of shaking and of separating the gold from the sand, but the above are the underlying principles.

From the concentrating apparatus the mineral passes to the roasting plant if it is to be subject to chlorination, or direct to the cyanide vats if that method is adopted. The object of roasting is to oxidise the gold, and thereby to render it more easily subject to the chlorination process. The drying and roasting is carried on in revolving apparatus, the mineral entering at one end and being discharged at the other, dried and oxidised, the revolving cylinder in which it is passing being subjected to heat during its journey. From the roasting apparatus the mineral passes to vats with false perforated bottoms. When the cover of the vat is closed and made gas-tight, chlorine gas is allowed to pass up through the false bottom, through the mass of the mineral, the gold oxide being formed into chloride. When the chlorination is complete the gas is turned off, the cover of the vat removed, and the vat filled with water to the level of the top of the mineral. The ter-chloride of gold that is formed being soluble in water is carried off with the water as it is run through the vat. A prepared solution of sulphate of iron is added to the resulting solution, which throws the gold down as a brown powder. This is collected, dried, and smelted into ingots.

In the cyanide process, which is finding more favour at present than the chlorination method, the concentrates are taken directly from the vanners to vats, where they are treated with a weak solution of cyanide of potash which dissolves the gold. The cyanide solution is then taken to precipitating vats containing zinc shavings, where the gold is displaced from solution by the zinc, the former being deposited on the shavings. These are removed, dried, and smelted, the zinc passing off as fumes, and being collected, in the most economical plant, for future use, the gold being made into ingots as before. There are several variations of the cyanide method.

Goliath Crane.—A tall crane of travelling type which differs from the overhead travellers in the fact that it runs on the ground while the travellers run on overhead tracks, or *runways*, high up, clear of a shop floor and machinery. It comprises two tall **A** standards, which carry the gantry, or travelling beams. The crab or jenny runs along the latter, as in travellers. The methods of operation are as numerous as those of overhead travellers, modified by the travelling motions of the framings.

The original of the goliaths is the Wellington crane, timber framed. In this a jenny traverses the gantry beams, and its traverse, and hoisting motions are actuated by two sets of gear, one on each **A** framing. One set operates the traverse or racking motion by means of a chain passing over guide pulleys and anchored to the ends of the jenny. The other set hoists through fast and slow gears, and winch handles. The gears for travelling are on the bottom members of the frames, one on each frame, because of the tendency which the crane has to work diagonally in relation to the rails.

In the hand goliath fitted with a crab, the crab is operated by winch handles; and by single, double, and treble gears, similarly to a hand crab on an overhead traveller. In some cases two such crabs are fitted for convenience of lifting separately, and in combination. Some hand goliaths have crabs operated by an endless rope dependent from a grooved pulley actuating gearing. Steam goliaths may have the engines on the crab, in which case the framing is travelled by pitch chains, and sprocket wheels. Many of these have been built, and if properly made they work easily. An alternative is gears and shafts, which if stiffly designed do not work in so jerky a fashion as pitch chains often do.

When the travelling is done from above, it is through a shaft which runs alongside one of the gantry beams, generally a square shaft which is driven by bevel wheels moving with the crab. This device is the same as that used on overhead square shaft traveller drives. The driving sprocket wheels are on the ends of the square shaft. Electrically driven goliaths are usually made with separate motors for each movement. But the travelling motor is placed on the gantry, as in travellers, and drives the ground wheels through bevel wheel and shaft connections.

An evil incidental to the height of goliaths is the risk of working across the rails when travelling. This must be guarded against by rigid attachments of the gantry beams to the standards, and by having a wheel base long in proportion to the span. Sometimes goliaths are fixed, though strictly they should then be termed *fixed gantries*.

The framings of goliaths are either of timber, or steel-plated. Timber—red deal, or Memel—will last from twenty to thirty years with proper care. For permanent service, steel is generally preferable, and it is the only material suitable for hot countries. Steel framings are in the majority of cases built up largely of rolled channel sections, united with gusset plates, and braced with angles and bars. Only in the heaviest types is regular plating done for the standards. The main girders are built as single-webbed, or double-webbed box sections, in the lighter, and heavier cranes respectively.

The illustration, Fig. 97, Plate VI., is that of a 40-ton steam goliath crane (test load, 50 tons). The span is 66 ft. 7 in. to centres of tracks; the lift from the ground to the underside of the girders, 25 ft. The speeds are: lifting, 10 ft. per minute; travelling, 80 ft. per minute. The traverse of the crab is 50 ft. per minute. The crane is mounted on twelve wheels.

Fig. 98, Plate VI., is a very common and useful form of construction, the framing being built of timbers, which are cheaper, though not so durable as steel. The example is that of a 17-ton steam-driven type, with a span of 50 ft. to rail centres, and clearing 88 ft. to underside of the truss. The engine on the crab operates all the motions, the travelling being effected through the square shaft, and bevel wheels seen clearly on the right-hand side. The speeds are: lifting, 20 ft. per minute; travel of crane, 100 ft. per minute; traverse of crab, 40 ft. per minute.

Gouge.—Wood-worker's gouges are of two main types; the paring, and the firmer, Fig. 99, A, B. The firmer gouge is ground on the outside of its curve, and for this reason is often called an *outside gouge*. The paring

gouge is ground on the inside. The firmer will only cut when it is tilted to a considerable angle from the surface of the wood, while a paring gouge cuts when parallel with the surface. The latter, therefore, will make a straight cut, because the body of the gouge acts as a guide, but as it will dig in if tilted, it cannot travel further than its own length from the edge of the wood without the handle coming in contact with the work. Occasionally this is obviated by cranking the shank and handle, but the ordinary length of gouge is sufficient for most purposes. Paring gouges are made long and thin compared with firmer. The firmer gouge is made stout, because a mallet is frequently used to drive it. A paring gouge is usually pushed by hand only.

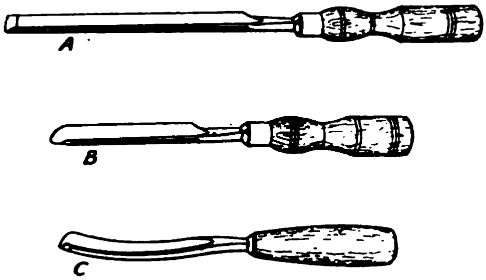


Fig. 99.—Gouges.

Both paring and firmer gouges vary in curve and in width. In the smallest sizes their curve is almost a semicircle, but in the larger sweeps even the widest gouges only represent a very small arc of their curve. The gouge employed for cutting to any given radius should usually be itself of a smaller radius, so that it can clear away the material within the radius without its corners digging in, and the middle part of its cutting edge doing comparatively little. If, on the other hand, the disparity of radius between work and gouge is very much, a great many more cuts are required to finish neatly to the line. For carving, and gouging recesses, and in core box work, firmer gouges curved in the direction of their length, known as bent gouges, Fig. 99, c, are often more convenient than straight ones. Wood-turning gouges are long, and stout, and have long handles.

Gouge Slip.—A slip of oilstone or emery, used for imparting a keen edge to gouges in the same way that an ordinary oilstone does to chisels. A slip is employed for gouges because, owing to their curved cutting edge, they cannot be sharpened on a stone with flat surfaces. The gouge is generally held stationary and rubbed with the slip. Slips are made with convex edges of varying radii to suit as nearly as possible the ordinary curves of gouges. *See also* **Hone.**

Governors.—A governor for a steam engine or water wheel consists of two or more revolving pendulums usually loaded by a central spring or weight to enable higher speeds of revolution to be run with an increase of power. When not thus arranged on a central spindle, it is usual to place a spring controlled weight in the flywheel, and the power being great is employed to shift and hold the eccentric which drives the valve. Governors are employed either to do this directly, or to do it slowly through the intervention of gearing, or they may control a throttle valve also, in this last instance so serving always to bring the engine back to normal speed, which cannot be done by the governor which controls a Corliss or similar trip gear. In this case, if it is desired that the engine should always be brought back to normal speed, a supplementary governor is employed which, by means of a left and right screw coupling in a rod, can be made to alter the length of the trip rod of such a gear, so that the engine may regain its normal speed while the trip catch is being still held up to an early or late trip to suit the load.

In gas engines, hit and miss regulation is effected by means of inertia governors, which consist of a weight which forms part of the gas valve push mechanism. The variation in the speed of the engine brings the inertia into play and causes hit or miss on the valve spindle.

See **Crossed-Arm Governor, Gas Governors, Parabolic Governor, Pickering Governor, Porter Governor,** &c.

In order to work correctly it is necessary that when an engine increases its speed because of reduced load, the governor shall not rise so far as to curtail the amount of steam sufficiently to reduce the speed of the engine to normal. Similarly when speed falls below normal, the governor must not drop sufficiently to turn on

so much steam as to raise the engine speed above normal. A governor which does this is said to hunt. If an engine runs at two widely different speeds when loaded heavily or lightly, its action on the steam admission apparatus must be increased. Governors are adjusted to such conditions by varying their revolving weights, or their control weights or springs, or by alteration of the links which communicate the movement of the governor to the valves, &c.

Other forms of governor are the gas-holder governor, which, as the holder fills with gas, moves the apparatus which shuts off the air supply to a producer. Many other forms of governor are in use which serve to regulate pressures in gas mains, and water supply in turbines, &c., to keep hydraulic pumps at such a speed as to maintain even pressures, and so on.

Grabs.—A particular type of excavating machines which derive their name from the closing, or grabbing action of the hinged buckets. The grab closes in the act of lifting, without any intervention beyond the tug of the suspension chain or chains.

Grabs are of *single*, or of *double chain* types. The choice of one or the other kind must be governed by circumstances. For regular and permanent service, and where there is a large proportion of broken rock, the double chain type is generally preferred. For occasional use the single chain is quite suitable. The reason why there may be hesitancy about having a double chain grab is that a special crane, or special attachment to a crane is necessary for its operation, while a single chain grab can be operated from any crane. On the other hand, in some cases the mechanism in

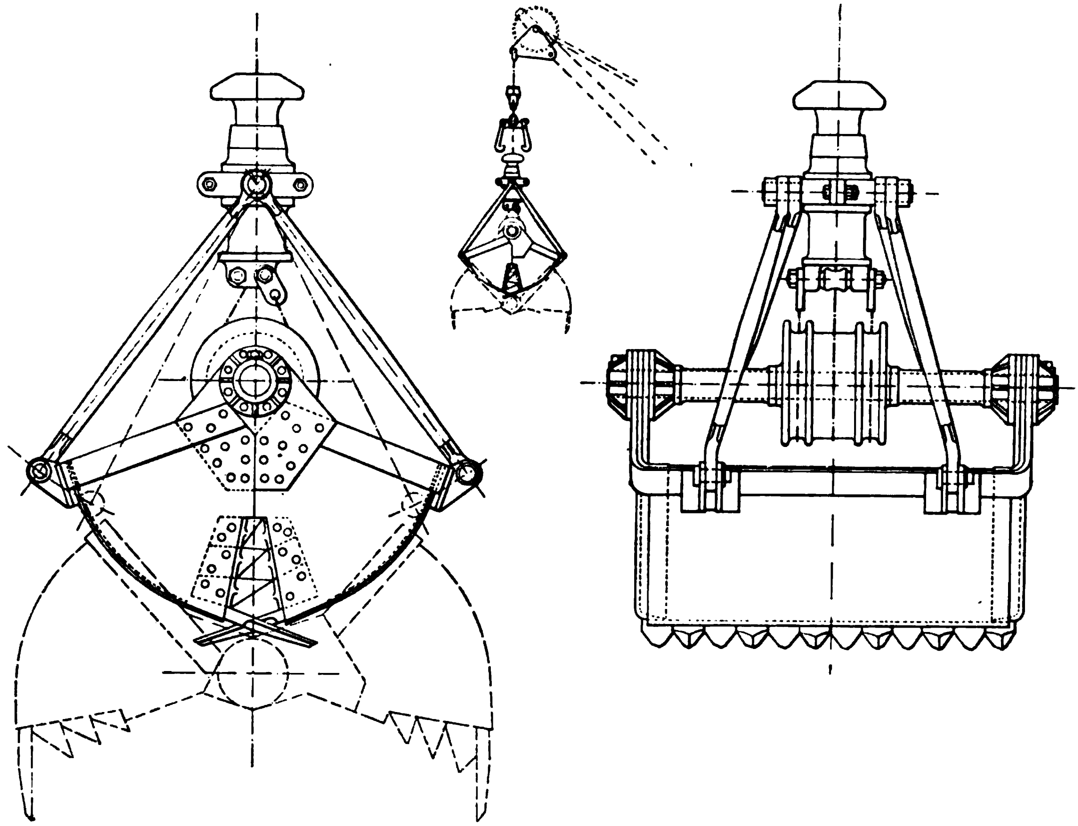


Fig. 101.—Priestman Grab (Plated).

the single chain grab for opening and closing is complicated, and liable to hitch. This usually consists of dogs, or catches, which act in conjunction with a suspension ring hung from the jib head, or with a special form of chain drum on the grab, the ring being adjusted to suit different heights of lift. If the grab hitches in boulders, it cannot be lifted without gripping hooks, or requisitioning the services of a diver.

From another point of view grabs are divisible into *plated*, and *tined* grabs, the latter being *half tine*, or *whole tine*. Another group is the *clam shell*, used specially for cylinder sinking for foundations.

Plated grabs are plain, and usually without teeth, or tines. They are used for grain, mud, watery sand, &c. Short tines or teeth are added when some penetrative power is desirable.

Tined grabs are half tine, or whole tine. In the first, about one-half the bucket is of plate, the other half of tines riveted to the plates, and having the teeth interlocking. The whole tine grabs have no plates, but teeth only, bolted or cottered into a strong steel framing, and maintained at equal distances apart away from the framing with straps. The spaces between the tines being always open, do not permit of lifting loose material. They are suitable for coke, blasted rock, and stiff mud.

The clam shell grabs are sometimes termed the *orange peel grabs*, because of the appearance of the opened tines. The buckets, three, or four in number form, when closed, a hemisphere, so that each one is triangular in outline, and hinged at the bases of the triangles. These are plated grabs, sometimes fitted with short tines, and generally of small dimensions for working within cylinders.

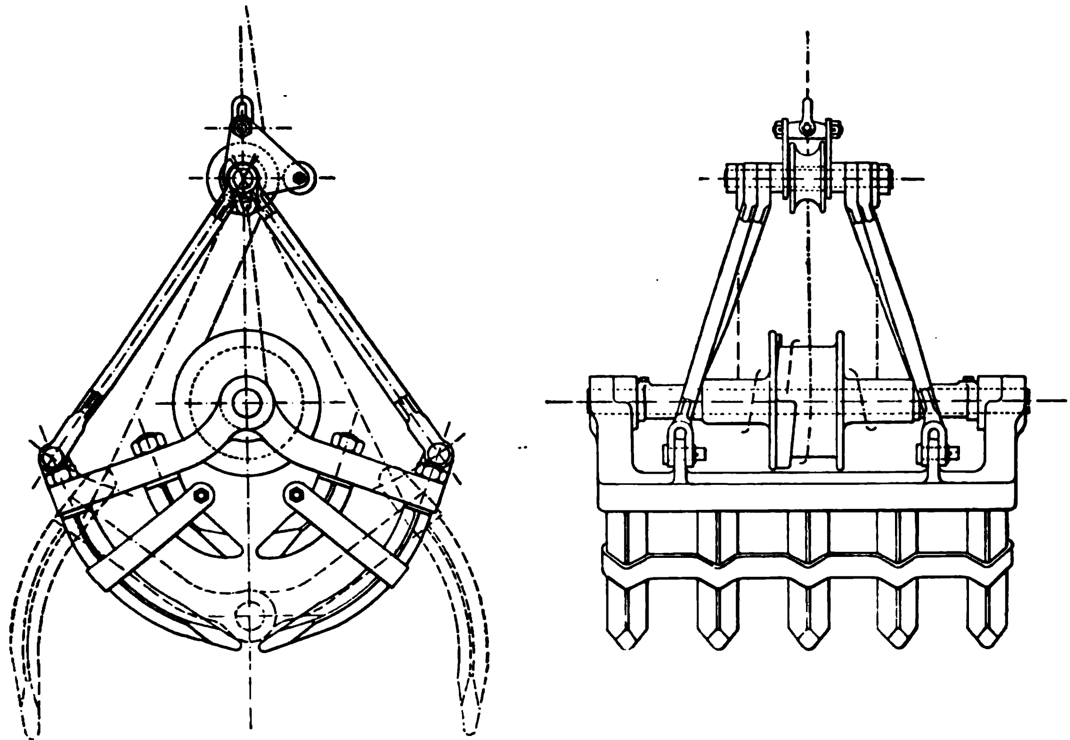


Fig. 102.—Priestman Grab (Tined).

There are ten or a dozen different grabs in service, of established reputation, the best known being Priestman's, Hone's, and Wild's. The chief feature of them all is that while the crane provides the mechanism for lowering and lifting, the rest of the work is done in an automatic manner. Chains, wire ropes, dogs,

sleeves, or other adjuncts open the buckets and close them on the spoil, and open again to discharge it at the proper moment.

Priestman's grab, Fig. 100, Plate VII., and Figs. 101, 102, constructed by Priestman Bros., Ltd., is a two-chain or wire rope form, one to open, the other to close the grab and raise the load. The principle of operation is as follows:—It differs from ordinary types, in having two chains, one being for lifting and lowering the grab and its load from the main

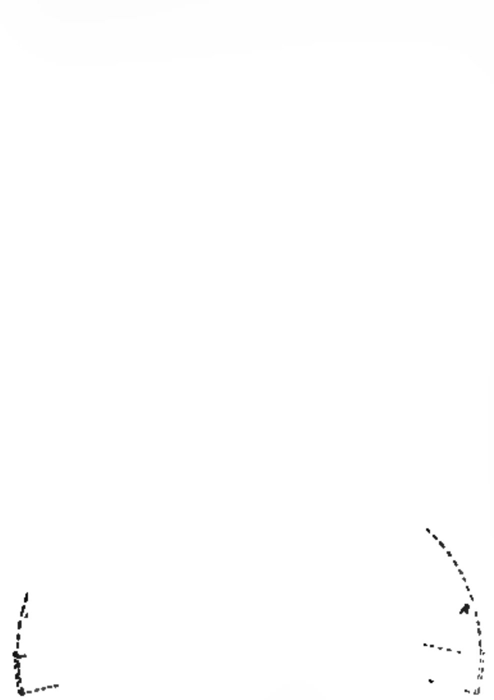


Fig. 104.—Hone Grab.

drum or barrel, the second a small chain, the sole function of which is to open and close the buckets. Either can be operated at will by its own separate levers at any vertical position whatever of the grab. And to permit of doing so instantaneously, the lever for the main chain actuates its drum through friction gear, and an automatically worked drum and brake to the small chain, or rope.

The hoisting drum calls for no further comment, but the apparatus for the opening chain or rope consists of a drum to which a steel coil is attached. As the grab descends, tension is put upon the coil which is sufficient to rewind the drum as the grab is lifted, and so gathers in the chain or rope for opening the grab.

The Priestman grabs deservedly take a very high rank in public favour. Most of the great harbour engineers have used them. They have been employed at the Southampton docks, the Preston, Barry, and Swansea docks, and on many other public works. The larger grabs will easily handle at the rate of 1,000 to 1,500 tons of clay or mud in a day of ten hours. The largest Priestman grab yet made is for lifting ore; it weighs nearly 8 tons and has a capacity of about 150 cubic feet.

The Hone grab, which is in extensive use for many purposes, such as the handling of coal, and other materials, and for contractors' work generally, is constructed by the Thames Ironworks, Shipbuilding, and Engineering Co., Ltd. The photo, Fig. 103, Plate VII., shows its general appearance, while the drawing, Fig. 104, renders those details of the mechanism clearer which cannot be properly seen in the photo. Its construction is as follows:—

The buckets A A, Fig. 104, move around pivots *a a* at their outer portions or haunches, contrary to the usual practice of pivoting near the centre. This, as may be shown by diagrams, gives a larger opening for grabbing, encloses a greater quantity of material, and gives a larger clearance space between the back of the grab and the material which is being cut, so lessening the friction. The grab can be worked with any crane, and is actuated by a ring hung from the jib head. The essential actuating mechanism comprises a slide block fitted with sheaves, a crosshead, locking pin, and releasing lever.

The buckets A A, Fig. 104, hinged to the main frame B at *a a*, are opened and closed by the sliding of the rods C C, guided vertically in the four angles D D, by the crosshead E, to which the rods C C are connected. The crosshead has a fixed vertical central pin with a semicircular notch across it. The top end of the pin is so arranged as to enter a vertical hole in the bottom of a rising and falling sheave block F, and it is to the bottom extension of this pin, formed into jaws, that the rods C C are attached. The sheave block F moves vertically

PLATE VII.

Fig. 98.—17-Ton Steam Goliath, with Timber Framing. (Ransomes & Rapier, Ltd.)

Fig. 100.—Priestman Grab, operated by Portable Steam Crane.

Fig. 103.—Hone Grabs.

To face page 114.

like the crosshead between the four angles D D, and carries two loose pulleys G G. The crane chain is reeved round these pulleys, and over one, H, above; and anchored to the under side of a circular plate J, which receives the top sheave, and through which holes are made for the chain to pass freely. It also secures the top ends of the four angles D. The loose ring actuates the grab through the lever K, which is swung on a locking pin L, and counterbalanced at M, so that it is free to rise. The locking pin L fits into a horizontal hole through and at the bottom of the sliding block F in such a position that half its diameter passes through a notch in the vertical pin on the crosshead, while the locking pin has also a notch in it, so arranged that when the two notches come opposite each other, the crosshead pin is free to become disengaged from the sliding block. The locking pin is kept always locked by a vertical stop and balance plate. Two stop pins are fixed to the plate, and the long end of the releasing lever is always bearing against the top one by the action of its balance weight.

When the grab rests on the material, the ring being hung at the height suitable for discharging, with the crosshead at the bottom of the guides, and the sliding block at the top of the guides, the latter will run down by its own weight, and that of the chain, until the crosshead pin enters the hole in the bottom of the sliding blocks and locks the machine. Digging commences on hoisting the crane chain, until the grab is closed around the material by the pulling of the sliding block and crosshead up the guides. The grab is then lifted far enough through the ring to permit of the depression of the long end of the lever K by the ring, which, after passing through, is swung back against the top pin. On lowering the grab to discharge, the long end of the lever is caught against the top edge of the releasing ring, lifting the stop plate, and turning the locking pin until the two notches come opposite each other. This releases the crosshead pin from the sliding block, and with it the rods and blades. At this stage an oil cylinder N fixed to the top plate J, with a piston descending, acts as a cushion, preventing shock, and shattering of material. After lowering clear of the ring, the releasing lever and locking pin resume their normal positions, ready for another load. The Hone grab is also constructed with another form of discharging gear, whereby it is opened when resting on the material without the aid of the suspension ring.

These grabs are made in various types, with and without tines for different materials. They are also built in circular form with four blades, forming a hemisphere when closed, for cylinder sinking and for stiff clay. Some of the biggest grabs ever built are of the Hone pattern; among them may be mentioned one constructed to the order of Sir John Jackson for the Dover Harbour Extension Works. One of these has brought up a ledge of rock measuring 7 ft. by 4 ft. by 4 ft. thick, in one lift; and in another, a piece 10 ft. by 6 ft. by 2 ft. 6 in. weighing about 10 tons. Others have been built for Sir W. Pearson for the Admiralty Works at Dover, the largest one having a capacity of 160 cub. ft., and weighing over 10 tons.

Grabbing is easy work in soft materials. Grain is lifted in this way, and also coal and coke. For the penetration of tough and hard soil the Gatmell and Batho machines have had a good reputation. In some designs a spear-like arrangement is fitted to assist in the work. But generally the weight and momentum of the grab, and some penetrative power due to the closing action is all that is available. With the whole tine grabs, hard clay can be excavated. Work is now being done with these, which a few years ago would have been considered impossible.

The work of the grabs lies in excavations for which neither the dredger boat nor the sand pump would be adaptable. Its special place lies in confined situations; but it is often used in open spaces, where it can be operated by a crane or a goliath. The great value of the family of the grabs lies in the fact that they are comparatively cheap, costing far less than any other form of excavating appliance, and that with one or two exceptions they can be operated by any crane. Also they can be set to work anywhere on land, or over water, within caissons, or on outside constructions. Moreover, the forms of the buckets, or clams,

or tines can be modified to suit the nature of the soil being grabbed; soft, or hard, sand, mud, clay, gravel, or broken rock. They are penetrative in character, and can be used wherever a crane or transporter will reach. Their action is very rapid, and the aggregate day's work is often very imposing.

Grade, Grading.—The determination of some particular quality of metal, alloy, or other material. It applies to the separation of one kind of iron from others, the different shades of grey, or mottle, and specifically to the composition of grinding wheels, as mentioned under that head.

Gradient.—A departure from a truly horizontal plane in permanent way. The gradient gave rise to much anxiety and controversy among the older railway engineers, when engines were much less powerful than they are now. Some of them were worked by stationary engines, since taken by locomotives.

The *undulating theory* was, that lines constructed in a series of undulations were as economical as those which were level, because the momentum acquired in descents would be utilised in ascending the opposite inclines. Akin to this was the question of whether in carrying a line over an elevation the undulating system should be adopted, or the main portion of the line be level and the gradients concentrated. The London and Birmingham line is an exemplification of the first, the Liverpool and Manchester of the second.

The question of gradient affects the descent when the rails are greasy, because of the extra braking power required.

The steepest gradient in England is the Lickey incline near Bromsgrove on the Birmingham and Gloucester line. This is 1 in 37½ for a length of over two miles. A pilot engine is necessary for making the ascent, and the use of brake vans in the descent.

Grain—*In Cast Iron.*—If a piece of cast iron is fractured, the aspect of the broken face varies not only with the quality of the iron itself, but also with the mass of the casting, and the manner in which it has been poured and cooled. It is not at all difficult for an experienced man to judge correctly of the quality of an iron by the fracture alone. All foundry men have not this experience, but it comes to most who have made a study of fractures.

Speaking generally, a very fine close-grained iron is weak, a fairly open grain is strong, a grey dull tint denotes weakness, a silvery grey, strength; a mottle, strength and toughness combined.

But fineness and coarseness of grain depend mainly on mass. A small section of metal has fine grain throughout, a large mass has fine grain close to the outside, but the crystals increase in dimensions towards the centre. The reason is that as metal cools it shrinks away from the central portions to the cooler faces, and this produces the arrangement of crystals named above—large because cooled slowly. In extreme cases the central parts of a casting are open and spongy because of the insufficiency of metal to supply the loss due to shrinkage.

Grain in Wrought Iron and Steel.—This is fully as important as the grain in cast iron. Speaking generally, steel is fine-grained; and wrought iron if suddenly fractured shows a coarsely crystalline grain which might almost be mistaken for that of cast iron, but the same specimen if slowly drawn asunder will show no grain, but a bundle of fibres. As a rule the higher the content of carbon in steel, the finer is the aspect of the grain in the fractured surface, but if any steel is overheated, it will show a coarser texture. Annealed steel has a coarser grain than hardened steel. Generally, too, in iron and steel, the best qualities show a higher lustre than the inferior ones.

Grain in Timber.—In wood the grain runs lengthwise with the tree trunk, and when cut transversely to the length, what is called *end grain* is exposed. A surface in line with the fibres is *with the grain*. Wood is described as straight-grained, when the fibres are straight; crooked, or curly-grained when wavy; or cross, or short-grained when the fibres cross a piece of sawn wood at an angle instead of running parallel from end to end. Close-grained when the wood is dense and heavy, and its fibrous character not very apparent. Open-grained when the contrary.

A piece of wood can be split with the grain,

but across the grain it must be sawn, or if sufficient force be applied, it may be broken irregularly, leaving jagged ends. The tensile strength of wood is very much greater in line with its grain than transversely, and so also is its ability to resist torsion, for the fibres are very easily separated from each other, by comparison with their tenacity lengthwise. It is across the fibres also that shrinkage, swelling, and warping take place. This is because the fibres, which may be considered as bundles of fine tubes which readily absorb or give up moisture, swell and shrink in diameter, but not appreciably in length.

Grain Rolls.—Mill rolls that are not chilled, but made of a tough close-grained quality of cast iron, poured in dried sand or loam. Roughing rolls are of this class, chilling being usually reserved for finishing rolls.

Gramme.—The gramme is the unit of weight in the metric system, and equals the weight of a cubic centimetre of distilled water at 0° C. The multiples and subdivisions of the gramme are denoted by the Greek and Latin prefixes adopted for the **Metric System**.

The following table gives the relation between the various weights and their values in avoirdupois :—

	Grammes.	Cwt.	Qr.	Lb.	Oz.	Dram.
Milligramme .	$\frac{1}{1000}$	...	...	...	...	·00056438
Centigramme	$\frac{1}{100}$	...	...	...	...	·0056438
Decigramme .	$\frac{1}{10}$	...	...	...	...	·056438
Gramme .	1	...	...	...	...	·56438
Decagramme .	10	...	...	...	...	5·6438
Hectogramme	100	...	...	...	3	8·4383
Kilogramme .	1.000	...	...	2	3	4·383
Myriagramme	10,000	...	...	22	0	11·8304
Quintal . .	100.000	1	3	24	7	6·304
Tonne . .	1,000,000	19	2	20	9	15·04

The power of cranes, &c., is stated in countries using the Metric System in kilogrammes, and as 1,000 kilos. roughly amount to 19½ cwt., a near approximation to the power in English tons is obtained by omitting the three noughts on the right and calling the remaining number tons. Thus a crane to carry 20,000 kilos. might be considered as a 20-ton crane; the exact equivalent is 19·6 tons. Any number of kilogrammes may be changed into tons by multiplying by 2·2 (1 kilo. = 2·2 lb.), and dividing the product by 2,240 (2,240 lb. = 1 ton).

Gramme Machine. — One of the first dynamo-electric machines, the invention of M. Gramme. The Gramme armature was of the "ring" type, having a smooth core with the conductor windings of wire laid upon its inner and outer surface. Thus only the wires upon the outer periphery cut the field lines of force (*see* **Dynamo**), the inner windings serving merely as connections, so that half of the copper used was practically idle wire so far as the induction of current was concerned.

This type of armature was succeeded by the "Drum Armature," having all its conductors on the outer surface, which in turn was developed into the "Slotted Core," drum, or bar-wound. Then followed the most modern form of winding, now used for all sizes of armatures wherein the coils are previously formed in moulds, insulated and laid in slots below the surface of the core (*see* **Dynamo**). The Gramme dynamo was much used in the early days of electric lighting, when it was the practice to run large numbers of arc lamps in series, but is now (in its original form) practically obsolete.

Graphics, or Graphic Statics. — The methods of estimating stresses and strengths by laying down lines to scaled and proportioned dimensions, as distinguished from their estimation by mathematical calculations.

Graphite, Graphitic Carbon.—*See* **Carbon, Cast Iron, Iron.**

Grate Area.—A dimension which varies with different systems of stoking adopted, whether by natural, or forced draught. It is essentially related to heating surface, and consumption of fuel and water. The amount of grate area is limited in any boiler. If large efficiency is required this must be sought for in accelerated combustion. The length of a grate is limited by considerations of stoking, and its width by the width of the furnace.

Graver.—A triangular tool used in hand turning.

Graving Dock.—A dry dock, from which the water can be excluded for a season to permit of effecting repairs to the hulls of vessels.

Graving docks should be situated in sheltered positions, instead of opening out directly into a tidal channel. This is done to permit a vessel to lose the way she may have acquired, and enter in smooth water conditions, and also to afford protection from winds and currents. It is difficult for a vessel to enter a narrow entrance without causing damage to it, or herself unless such protection is afforded. The gates also suffer if exposed to the action of waves and currents.

Graving docks require deep foundations to resist hydrostatic pressure from below, when the subsoil is charged with water, and the dock emptied. The best built section is an inverted arch, or brick *invert.* A natural rock foundation is better than made foundations of masonry, concrete, or timber; or than those of a composite character, as timber, stone, and concrete. The dock walls are generally built of sheet piling, lined with brick-work, and concrete, stepped to receive courses of granite. Sills for the gates have to be built, and paved with granite, and provision made for the **Dock Gates**. A pumping installation is necessary, with discharge chambers, and culverts.

Gravity.—The law of universal gravitation states that:—Every particle of matter in the universe attracts every other particle with a force acting in the direction of a straight line joining the two, and whose magnitude is directly proportional to the product of the masses and inversely proportional to the distance between the masses. This, perhaps the most famous of Newton's Laws, has stood the test of two centuries of mathematical calculation, and has not only proved sufficient to cover all experiment, observation, calculation, and verification, but has provided a means of prediction and discovery—as in the case of Neptune. But as in certain other cases where observation of, and deduction from phenomena have revealed a law, we are ignorant as to the *cause* of gravitation. Theories in abundance have not been lacking, but not one has proved convincing. In one sense the attraction of gravity is like magnetic and electric attraction, the force depending on distance, but while magnetic attraction exists only among certain bodies, gravitation acts universally.

The intensity of gravity at the earth's surface is measured with very great accuracy by the swinging of a pendulum. In a simple pendulum, $t^2 : \pi^2 :: l : g$, where t = time of one oscillation, in seconds; $\pi = 3{\cdot}1416$, the relation between diameter and circumference of a circle; l = length of pendulum; g = acceleration due to gravity. Then $t^2 g = \pi^2 l$, and hence $g = \frac{\pi^2 \times l}{t^2}$. The value of g, however, varies. At Greenwich it amounts to 32·191 feet per second, per second; at the Equator 32·091; at the North Pole, 32·255. (The repetition of the phrase "per second" means that a body falling from a state of rest acquires a velocity of 32·2 feet per second at the end of the first second, but at the end of each succeeding second its velocity is greater, for at the end of each second it has an *acceleration* of 32·2 feet per second.) The value of g is less at the poles, (1) because the earth is an oblate spheroid, and the distance to the centre of the earth is less at these two points, and (2) because the centrifugal force at the equator, due to the earth's rotation, tends to rob a body of the effect of gravitation. For all practical purposes, however, the acceleration of gravity may be considered as 32 feet, (981 centimetres), per second, per second.

For the formulæ by which problems in dynamics concerning motion under gravity are solved, see Vol. I. p. 16, under **Acceleration**. The **Specific Gravity** of a body is its weight as compared with that of an equal volume of water. *See also* **Centre of Gravity**.

Gravity Ammeter.—An early type of ammeter, in which the current to be measured was passed round a series winding upon a hollow solenoid, inside of which was an iron armature or plunger, counterbalanced by a lever and weight. The magnetic field inside the solenoid pulled the plunger down against the gravity of the weight through a distance dependent upon the current passing in the coil. The lever having also an indicating pointer attached, its angular displacement over a scale registered the current. This principle is now only used in cheap instruments where great accuracy or dead beat action is not of importance. Dash pots and other devices were used to damp the oscillations

of the needle, but its chief fault was the hysteresis errors. The gravity-controlled ammeter has been largely superseded by the "Moving Coil" type (*see* **Ammeter**).

Gravity Voltmeter.—In principle the same as the gravity ammeter, but having a high resistance winding, so that being connected as a shunt to the main circuit, only a very small current was passed through the instrument. As the amount of this current depended upon the E.M.F. in the mains ($C = \frac{E}{R}$ and R being constant), the deflection of its needle was an indication of the E.M.F.

Gravity Wheel.—*See* **Water Wheels**.

Grease Cock.—A brass fitting having a cup for the reception of tallow or grease at the top, and a cock below, which is opened when necessary, and the grease being melted by the heat of the cylinder runs down into the latter.

Greatest Common Measure.—Abbreviated G.C.M. A number which divides any given number exactly (without a remainder), is said to be a *measure* of that given number. Thus 3 is a measure of 6. If it divides two or more numbers exactly it is a *common measure* of those numbers. Thus 3 is a common measure of 6, 9, 12. The greatest whole number which will divide two or more others is the *greatest common measure*. 3 is obviously the greatest number which will measure 6, 9, and 12 exactly. If the G.C.M. (sometimes also called the Highest Common Factor, or H.C.F.) is known, unwieldy numbers may be reduced to smaller ones without affecting their ratio. In particular, fractions are reduced to their lowest terms by dividing numerator and denominator by their greatest common measure.

To find the G.C.M. of two numbers, divide the greater by the less; if there is any remainder divide the first divisor by it. Continue dividing the preceding divisor by successive remainders till nothing remains. Then the last divisor is the G.C.M. Example:—Find the G.C.M. of 95 and 110.

```
95)110(1
   95
   15)95(6
      90
       5)15(3
         15
```

The G.C.M. is therefore 5; *i.e.*, 5 is the greatest number which can be divided into both 95 and 110. To find the G.C.M. of three or more numbers, the greatest common measure of the first two is obtained, and then the G.C.M. of this common measure and the third number.

Find the G.C.M. of 18, 45, and 51.

```
18)45(2
   36
    9)18(2     G.C.M. = 9
      18

 9)51(5
   45
    6)9(1
      6
      3)6(2    G.C.M. = 3
        6
```

Hence 3 is the G.C.M. of 18, 45, 51.

In algebraical expressions the greatest common measure may sometimes be found by inspection. In the expressions 14 a^2b^3, and 21 a^3bc^2, the G.C.M. of 14 and 21 is 7; the letters common to both expressions are a and b, and the least indices of these letters are 2 and 1. Hence G.C.M. $= 7a^2b$.

In some cases it is convenient to resolve the expressions into **Factors**, when the greatest common measure will be apparent. Find the G.C.M. of $a^2 - x^2$ and $(a - x)^2$.

Here :— $$a^2 - x^2 = (a + x)(a - x)$$ $$(a - x)^2 = (a - x)(a - x)$$

From which it is evident the G.C.M. $= a - x$. The greatest common measure may also be found by successive division as shown above, but in this case it is sometimes necessary or advisable to employ certain devices not needed in arithmetical examples. (*a*) All the signs in a remainder may be changed if the sign of the first term be negative; (*b*) the divisor or dividend may be divided by any expression containing no factor common to them; (*c*) the dividend may be multiplied by any number containing no factor occurring in the divisor.

Greenheart—(*Nectandra rodioei*).—A hardwood from tropical South America. Its colour ranges from greenish yellow or white outside,

to dark brown at the heart. The tree is of large size, and its bitter secretion preserves it to a great extent from the attacks of insects. It is straight in grain, very durable, and so heavy that it sinks in water. It is used chiefly for dock gates, piles, and permanent work of similar character, where the expense of the timber and trouble of working it is a less important consideration than durability.

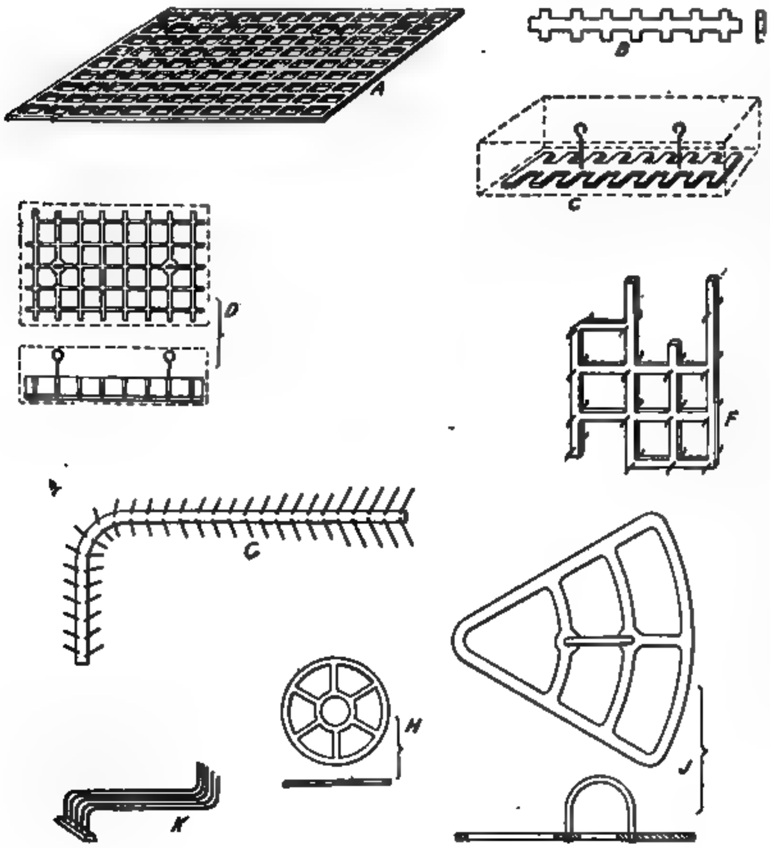


Fig. 105.—Grids.

It is much more durable than steel for these purposes. Its weight, dry, is from 64 to 75 lb. per cubic foot.

Green Sand Moulding. — Moulding in sand which is not dried subsequently, but which coheres sufficiently by the moisture present in it; and which resists the pressure of metal by virtue of the consistency imparted to it by judicious ramming, and the imperviousness of which to the escape of gas is counteracted by free venting.

Green sand is suitable for by far the largest quantity of work done in foundries. It involves no cost for drying, though some moulds are skin-dried, nor has it to be prepared specially, like loam. It includes mixtures of different sands found in various localities, and possessing different qualities; some being open, and more or less self-venting, others close and clayey. Some of the former are often used alone, like the red sands of Mansfield and Worcester, but generally the best and most varied results are secured by judicious blending and mixing. The clayey sands are ground in a mill. All sands have to be sifted before use, and moistened, and mixed with water.

Grey Iron.—*See* **Cast Iron.**

Gridiron. — A device used to a limited extent for affording support to vessels out of the water, for purposes of examination, and repairs. It consists of a number of logs laid in a parallel position on a masonry foundation, in a tidal basin. The vessels are floated on the grid-iron at high tides, and moored, and left exposed by the retreating tide. It can only be adopted when the range of tide is sufficient; and the operations are necessarily intermittent. Hence the floating, and graving docks, and slipways are preferable.

Gridiron Valve.—A plate, or cut-off valve, sliding on the back of a main valve.

Grids.—Iron framings used to sustain and stiffen the sand in cores. They vary with the dimensions, mass, and shape of the cores; comprising open lattice or chequered castings, with

or without eyes for lifting and setting the cores by, or wrought-iron rods. Their shapes are as infinite as those of their cores.

The elementary form of the grid is the lattice frame, Fig. 105, A, or often a solid plate. The bar section is usually from $\frac{3}{4}$ in. to 1 in. square. A standard pattern is kept from which grids of any size or shape are made by stopping off, or if necessary, by ramming up twice in succession. Such grids serve for nearly all rectangular cores, thick, or thin. If thin, nothing more than the skeleton plate is requisite as in A. If thick, rods are cast in on one side, or both, straight, or variously curved, or at angles, depending entirely on the core shapes.

B shows a grid which is little more than a plain bar, used for short cylindrical cores, one in each half core. C is of somewhat similar shape, but it supports a core of moderate depth and has eyes for lifting it by. D is a variation on this, being similar to the bars or stays of a moulding box, and used where the mass of the core is considerable. E is for a deep core, the rods cast in affording support round the edges of the core. In F the grid lies centrally, and the rods bent at the ends support the sand on each side. G is for a bend pipe having rods cast in at an angle, one grid being used in each half core.

Often in large cores the grids are of a much more skeleton-like shape, comprising a more open framework with wide spaces to lighten the mass, and having no rods, or a few only cast in. Special jobs require specially designed grids. Thus those for the cores of wheel arms follow the outlines of the cores H, J, as do those of cast pulleys. Those for the passage cores of cylinders are formed of bent rods, K following the curves of the core.

Eyes are cast in grids, or screwed into nuts cast in. The castings are made in open sand. Grids are swabbed with clay wash to help the adhesion of the sand.

When making grids, the getting them out of their castings has to be borne in mind. Many will come out, the castings being open on one side or face. But many are partly enclosed by metal, in which case they must be broken for removal, or the rods bent. They are therefore made capable of ready fracture or easy bending.

Grillage Foundations.—Applied to broad foundations of concrete on soft yielding soil, the broad area being necessary to distribute the central load as much as necessary. A modified design is that of steel beams of I section laid in rows singly, or in two rows crossing at right angles, resting on a shallow bed of concrete, and leaving space between which concrete is rammed.

Grinding.—Grinding occupies a large place in engineers' work, both as a roughing and as a finishing process. The grindstones, which were formerly the only agents available, have been supplemented, and in many cases supplanted, by the wheels of emery, corundum, carborundum, and mixtures of the two first-named. Grinding powders have but a limited application, chiefly that of lapping, although a large amount of this work is now done with solid wheels instead. The first applications of grinding wheels were valued most for their power of abrading hardened materials which cutting tools of steel would not touch, and the amounts of metal removed were small. Heavy reduction is a feature in modern grinding, which enables it to rival the work of the lathe on shafts, and spindles, so that often no turning at all may be done, but the work roughed out, and finished by the grinder.

Grinding has been a potent factor in the development of the milling cutter, since the old practice of softening a cutter and filing it up, and re-hardening, is no longer necessary, with the advent of variously shaped wheels of fine quality. Grinding has also helped to improve the construction of many machines, because of the facility it affords for truing hardened parts, which would otherwise be left soft; or hardened, and not corrected for the slight imperfections which the hardening process so often introduces. The following are a few of the principal classes of work effected by grinding in engineering shops:—

Dressing all classes of levers, rods, castings, plates, stove parts, &c., to give smoothness and good appearance, without any pretence at great accuracy, done on plain grinders, with or

without the help of slide rests. Fettling is included in this heading. Surfacing brasses, nuts, cotters, keys, and such work, where fair accuracy is essential, the grinder being in rivalry with the file, planing machine, and milling machine. Some sort of control over the work is usually provided by a sliding table, or rest, unless a disc grinder is used, when a flat face is obtained without such guidance. Truing flat slides, of comparatively large area, and close accuracy, done on planer type machines. Finishing hardened links and blocks of curved form, on machines with special milling cutters, saws, reamers, counterbores, &c., with special machines. Sharpening taps and the points of drills. From this brief outline it will be seen that there are few operations which may not be done by grinding, the notable exceptions being surfacing of very large areas on castings, for which planing or milling still holds the first place; large circular external or internal surfaces, as flywheels and cylinders, and certain profile work, which cannot be ground because of the inability of a grinding wheel to retain its shape constantly; though in some cases the trouble is overcome by using a

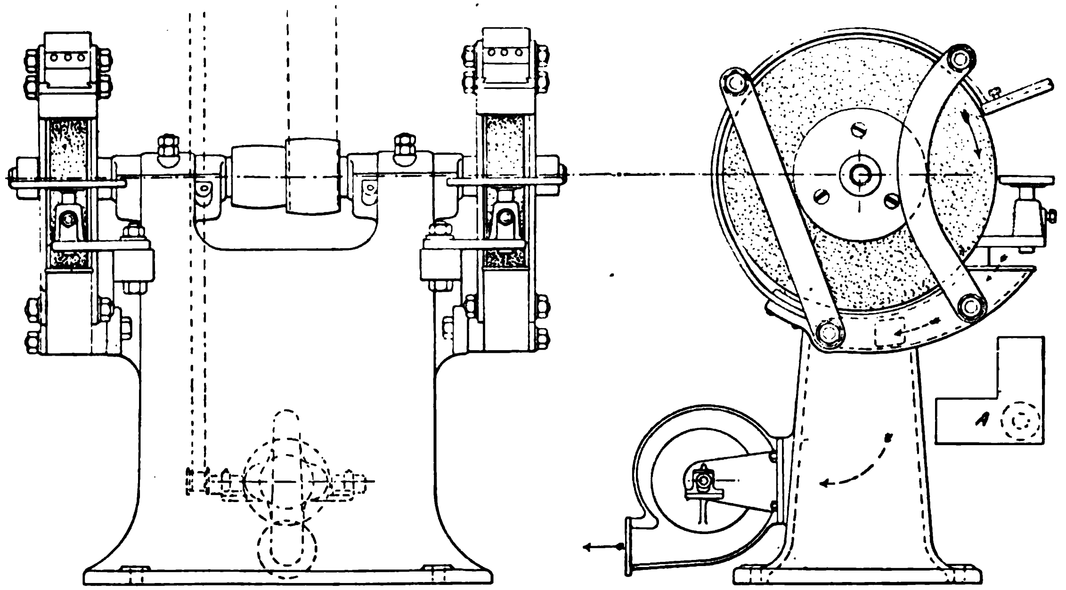


Fig. 106.—Plain Grinder.

devices to produce the radii. Lapping out holes and bushes to precise dimensions with small wheels or rollers. Grinding cylindrical shafts, spindles, rolls, collars, to within moderate limits on machines somewhat resembling the lathe in outline. Finishing spindles, collars, and gauges to the finest limits on high-class machines with micrometer adjustments. Under tool sharpening, several different kinds of operations are included; the plainest is that of grinding lathe and planer tools, followed by that of cutting knives, often of great length, for wood planers, and shears. Sharpening moulding cutters. Grinding the teeth of former which guides the wheel in the path required.

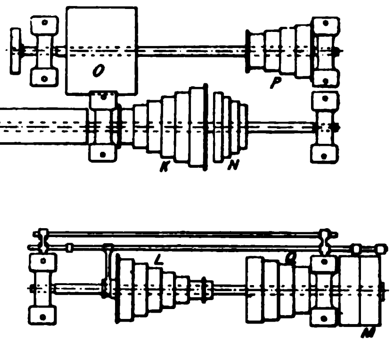
Grinding Lathe.—In the early days of grinding, when it was adopted chiefly as a means of truing hardened work, such as gauges, &c., the machines were modelled upon the ordinary lathe design, with headstock driven by cone pulley; poppet, and slide rest on which the wheel was mounted. In fact, many lathes were converted into grinders, by the addition of a grinding rest, driven by an overhead drum. The term has gradually been dropped, in favour of "grinding machine," because the resemblances to a lathe are not so obvious in modern grinders,

which are more suitably designed for the service required.

Grinding Line.—A line marked down the centre of each groove of a twist drill, as a guide in grinding the lips centrally. With the increasing use of drill grinders, which produce true results by means of the mechanism embodied in the construction, the necessity for this line is obviated, being only of value when hand grinding is done.

Grinding Machines.—The requirements of engineers' work have had the effect of developing a large number of varieties of grinding machines, from the roughest to the finest, for performing operations as outlined under **Grinding.** The chief differences between the types are those of relative accuracy of construction, and means of feeding the work or wheels. One peculiarity not found in other classes of metal-working machines is that the work may be held up and fed by hand during grinding, in common work, while with most cutting tools it must be gripped firmly with clamps or vice. We therefore find a number of plain grinders, of the type shown in Fig. 106, with flat rests simply, by the aid of which sufficiently true work may be done, in addition to the use of the flat faces of the wheels as a final correction for plane pieces. Between these machines and the precision grinder described later lie a vast range of types, which are ever increasing, and the principal of which will be found treated in these volumes, under special headings.

Two special points apply to grinding machines more than to those employing steel cutting tools, the necessity for preventing the particles of material, and emery, &c., from flying, and also from getting into the spindle bearings and slides. Their fineness and rapid abrading action render these precautions obviously necessary. Guards are now usually fitted around wheels, with the double object of preventing accident should the wheels fracture, and of confining the



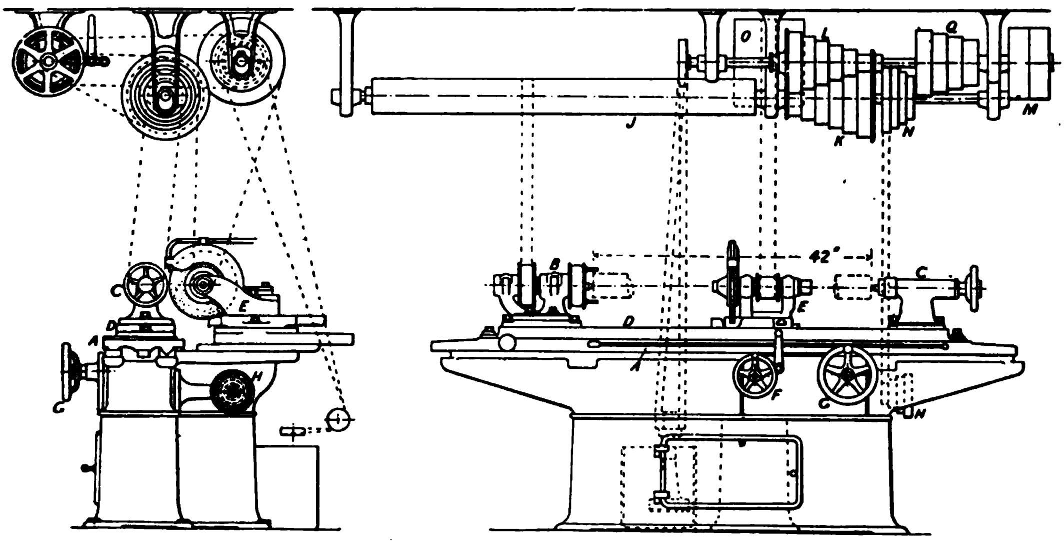


Fig. 107.—Universal Grinding Machine. (G. Birch & Co.)

grains of dust, which tend to fly off tangentially. In cases where water is not always employed during grinding, an exhausting device is generally provided, Fig. 106, a small fan sucking the flying particles directly they are produced, and depositing them quietly in a heap. Often the rests are hollow, and a draught is created through them, in order that the material shall be drawn away at the point of production. Where, however, a certain amount of dust cannot be avoided, bearings have overhanging caps or collars, and slides are covered with sheet-metal guards which may have to telescope

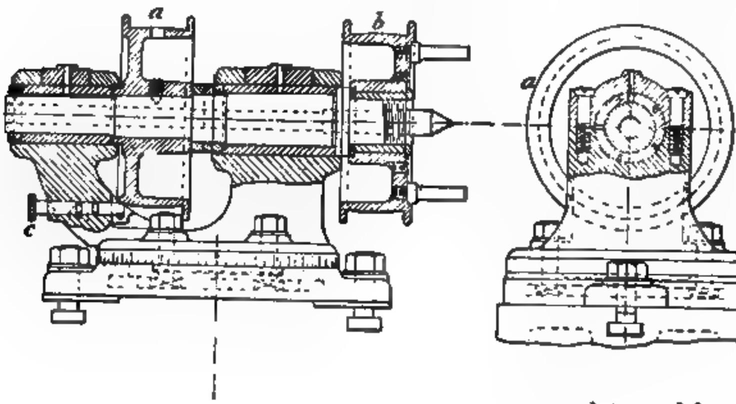


Fig. 108.—Headstock.

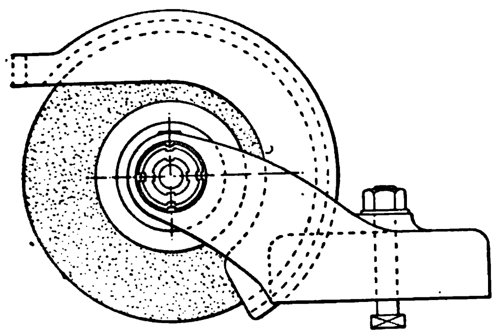
as the slides travel. One ingenious device where a travelling head is concerned lies in providing a sort of blind-roller fitting, carrying a waterproof covering, which winds or unwinds by means of springs, as the sliding head goes to and fro, thus protecting the slides at all times.

Another feature which is found in all high-class grinders is the inclusion of micrometer adjustments, for very fine feeding of wheel or work, some details of which can be best studied in connection with the machine here shown.

The essential features of a typical universal grinding machine are illustrated by the set of drawings shown in Figs. 107 to 114. Here we have the opposite condition to lathe turning, because the work, held between the head and tailstocks, is travelled past the grinding wheel, the latter remaining stationary, unlike a turning tool, which moves with its carriage. This practice is, however, not adopted in the largest grinders, because of the overhang of the table at either end occupying a large amount of shop space. Then the wheel carriage moves instead. Whichever method is pursued, a long belt-drum overhead is necessary, to follow the travel of the wheel or the headstock. Taking up the details of Fig. 107, the table A, running on the bed with a vee and a flat, as seen in the end view, carries the headstock B and tailstock C, supported by an intermediate slide D, which can be swivelled upon A and clamped, for tapered grinding. The wheel head E may be moved to and from the centre. The travel of the table, and of the wheel head are effected by hand, or automatically, the wheels F and G in front of the bed producing the first named, and the pulley H the second. A rack drive is fitted to the table, which reverses automatically, a dog clamped in the slot in the front edge striking the lever seen by handwheel F, and throwing a clutch over. The countershaft arrangements give a range of speeds to the long drum J, through the stepped pulleys K and L, driven by the fast and loose pulleys M. N, on the same shaft as K, drives down to H, providing suitable rates. The large narrow drum O driving the grinding wheel, is actuated from cones P and Q. O is made sufficiently wide to allow of the belt following the movements of the carriage E, which is swivelled upon its base for grinding very steep tapers.

Taking some of the parts in detail next, Fig. 108 shows the headstock B in section, plan, and end view. It has two pulleys, one, *a*, for driving the spindle as a whole, and another, *b*, for rotating work on dead centres, *b* running loosely

on a bush encircling the nose of the spindle. During this dead centre work the spindle is locked by a pin *c* entering into a hole in the flange of *a*, *c* being held in or out by a transverse pin going across grooves turned on its body. The bearing bushes of the spindle are split in five places, right through in one only—see the broken section in the end view—so that when the caps seen in the end view are tightened



down, the bushes are closed in equally all around. The head stands upon a base plate, and is graduated upon its bottom rim—so that angling can be done to any degree, for doing angular grinding supported only by the head, in a chuck, instead of between centres. The tail-stock C resembles that of a lathe very much, but it has a spring fitting which enables the spindle to give back slightly should the work between centres expand from heating, and so prevents distortion or warping.

The wheel head E is shown in section, plan, and end view in Fig. 109, from which it will be seen that the spindle runs in two coned bushes which are drawn into the head and locked by nuts as wear takes place. The grinding wheel is held in a dished flange which carries it back over the bearing to avoid overhang. A ring clamped with screws grips the wheel between rubber washers. In this head, as in the driving and tailstocks, complete provisions are made to exclude dust from the spindle bearings. A cast-iron guard encircles the wheel, leaving only as much exposed as is necessary for operating. A fitting for internal grinding, Fig. 110, is bolted down to the head E, Fig. 107, the large wheel holder being slewed round out of the way meanwhile. The feature of this attachment is the great length of spindle which has to project from the casting. Efficient bearing is secured by forming a coned fitting at the front end, and running the nose of the spindle therein, close to the grinding wheel, as well as supporting it in the shaft upon which the belt pulley is attached.

The follow rest, Fig. 111, is attached to the bed, so that the work slides past it during

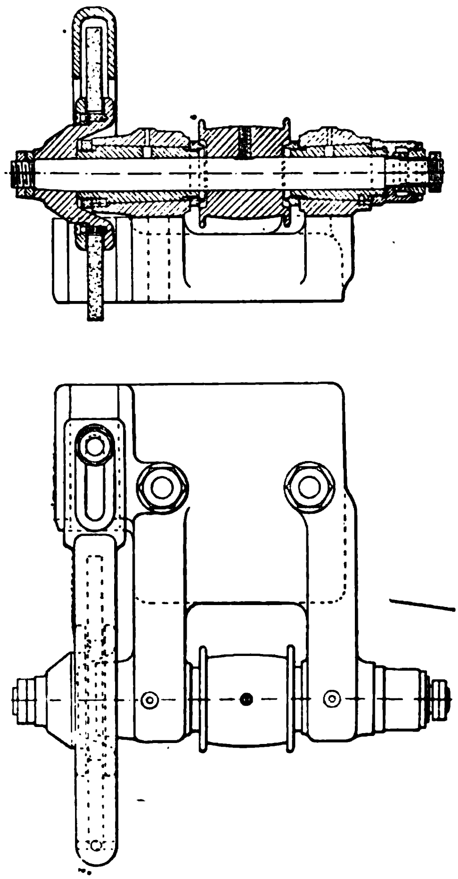
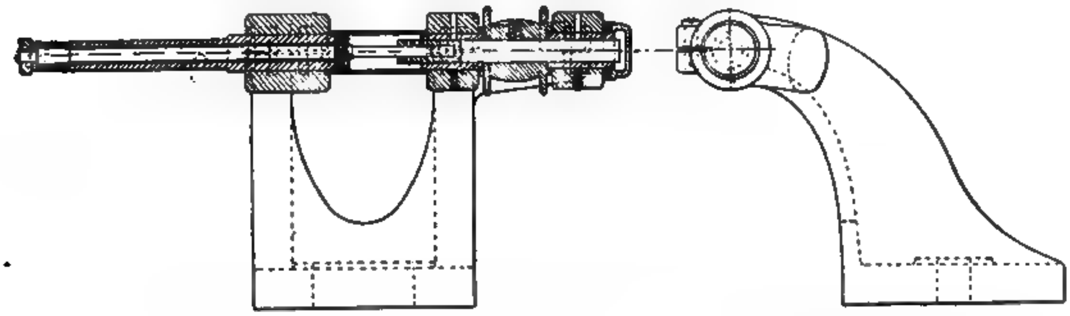


Fig. 109.—Wheel Head.

grinding. The two shoes which bear upon the revolving work, are screwed to a rocker casting pivoted in the main frame, and adjustable therein by a vertical and a horizontal screw pressing on extensions in a manner which is clear, and tilting it up or down. Fig. 112 shows an enlarged view of the shoes, and method of adjusting same.

A section through the slides of the wheel

head base is seen in Fig. 113, the main and the swivelling tables A and D being shown to the



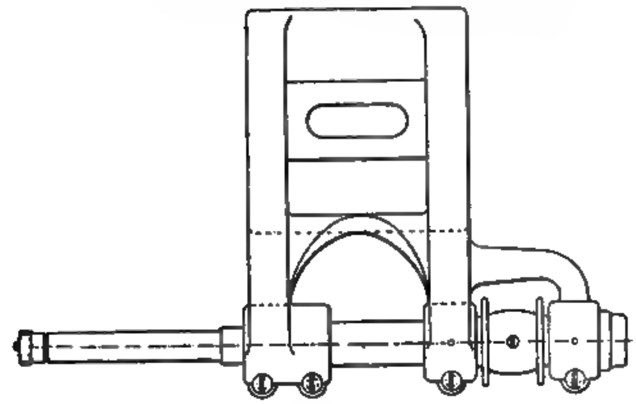


Fig. 110.—Internal Grinding Attachment.

left. Continuing our lettering from Fig. 107, the table B, tee-slotted for the reception of the head, Fig. 109, pivots by a large pin, and is

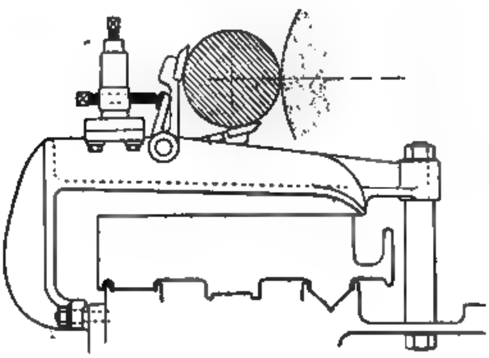


Fig. 111.—Follow Rest.

clamped with tee-headed bolts on a slide S, running on a swivelling base U, bolted to the bed V. The screw T is rotated, to move S, by the train of bevel gears actuated from the shaft W. The latter passes through the bed to the front, to the handwheel F (Fig. 107) with which is connected a feed device, Fig. 114, for operating by hand, coarsely or finely, or automatically, as the table reverses. In Fig. 114 the handle A revolves the wheel, and with it a shaft on which the cone clutch B is held with a cotter fitting, so that it may be pulled into contact with wormwheel C by screwing up the knob D. This is done when a fine hand feed is required, the worm E, rotated with a knurled knob, giving a very slow rate to the shaft, which is shown at W in Fig. 113. If the clutch B is thrown out, then A moves the wheel to or fro with rapidity. The automatic feed is

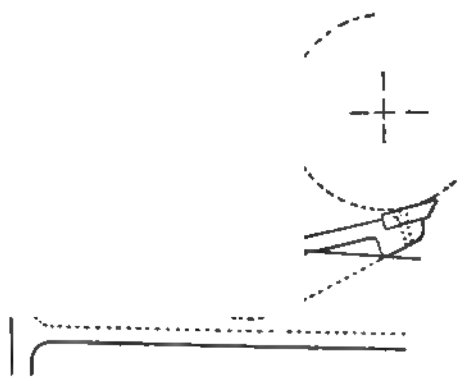


Fig. 112.—Shoes of Follow Rest.

produced by the lever F, Fig. 114, which is struck by the adjustable dogs bolted on the edge of the table A, Fig. 107, one dog being

seen in the left-hand view, Fig. 114. The throwing over of F moves clutches (not shown) inside the bed, reversing the motion of the table, so that it slides to and fro for a distance equal to the length of work being ground, plus a trifle of lap, in some cases. At each reversal the grinding wheel is fed up by a very minute amount; the lever F in falling over strikes a roller on the end of a lever G, which jerks a pawl H up slightly and causes it to partly rotate the serrated disc which is mounted on the central shaft. A spring plunger fitting in the end of G keeps H up to its work, or will hold it out of engagement if desired. The pawl J serves to impart a fine hand motion to get the wheel gently up to its cut before the automatic

Fig. 113.—Wheel Head Base.

Fig. 114.—Feed Device.

feed can operate. The machine is provided with pump and tank and fitted with trays and guards, and all arrangements for wet grinding.

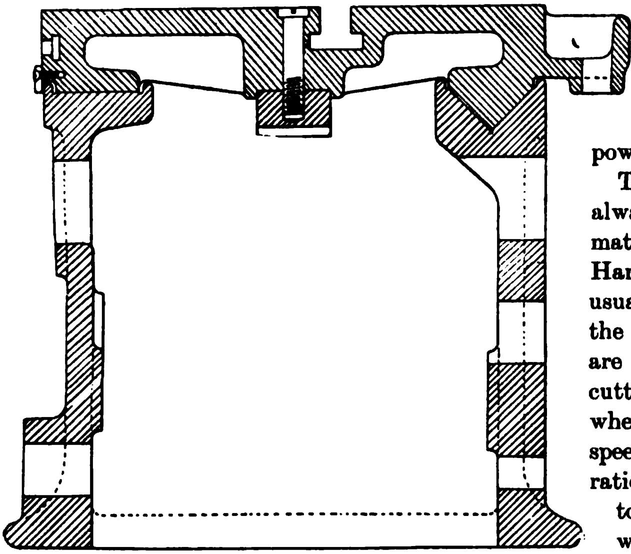


Fig. 115.—Grinding Machine Bed and Table.

Figs. 115, 116 show the essential difference between the two designs of machines mentioned previously, the first having the table, which carries the work, to travel; the second the wheel carriage to slide along the bed, while the work is stationary longitudinally.

Grinding Wheels.—The high development to which grinding machines have attained is due practically to the introduction of the solid wheels of emery, corundum, and other abrasives, enabling operations to be performed which were beyond the possibilities of the grindstone. The chief differences are that the wheels can be moulded into any shape, and graded to suit the class of work, while the cutting properties are far in advance of the grit stones. The two important points which determine the suitability of a wheel for its work are its degree of coarseness or fineness, and of hardness or softness. The first-named feature is settled by the size of the grains, the second by the character of the binding agent—the terms relatively applied to these being the "grit," and the "grade." Wheels are numbered according to their coarseness, depending upon the sieve number which the grains will pass through. Thus a No. 50 would pass through a sieve having 50 meshes to the square inch, but not through one having 60 meshes. The usual numbers range from 6 to 220, but neither the coarsest nor the finest are employed commonly for wheels, being reserved for abrasion as loose powders, or slips.

The selection of a suitable wheel is not always an easy matter, depending on the material and class of operation to be done. Hard and coarsely-graded wheels are applied usually to the rougher kinds of work; on the opposite hand soft wheels of fine grain are necessary for precise work, such as cutter grinding. The efficient operation of wheels depends also largely upon the relative speeds of wheel and work, since improper ratios may injure the wheel by wearing it too rapidly, or glazing it, or spoiling the work by undue heating. If a wheel is too soft for its service, the grains become parted too quickly, with consequent rapid reduction of diameter, while on the other hand a hard wheel does not give up its particles at a sufficient rate, and the ones in action becoming dulled with overwork, produce "glazing," a shiny state, at which cutting ceases, and the work is simply heated by the excessive abrasion.

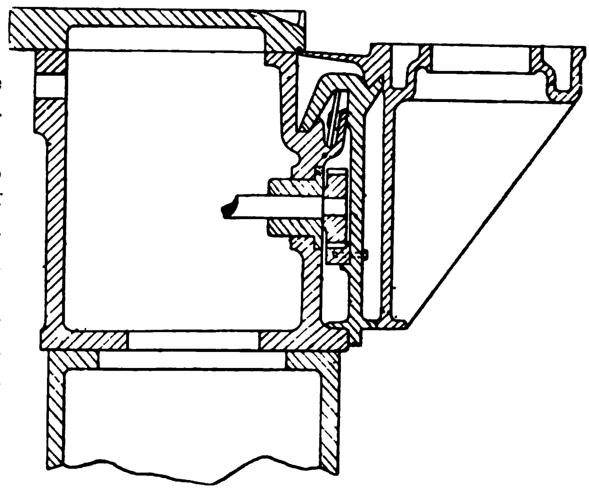


Fig. 116.—Grinding Machine Bed and Table.

Water may be used with grinding wheels

without affecting their stability or cutting properties. The usual peripheral speed imparted to wheels is 5,000 ft. per minute, higher or lower rates being applied in certain cases. The following table, from the practice of the Norton Company, shows the revolutions per minute for surface speeds of 4,000, 5,000, and 6,000 ft.

TABLE OF GRINDING WHEEL SPEEDS.

Diameter of Wheel in Inches.	Revs. per Min. for Surface Speed of 4,000 Ft.	Revs. per Min. for Surface Speed of 5,000 Ft.	Revs. per Min. for Surface Speed of 6,000 Ft.
1	15,279	19,099	22,918
2	7,639	9,549	11,459
3	5,093	6,366	7,639
4	3,820	4,775	5,730
5	3,056	3,820	4,584
6	2,546	3,183	3,820
7	2,183	2,728	3,274
8	1,910	2,387	2,865
10	1,528	1,910	2,292
12	1,273	1,592	1,910
14	1,091	1,364	1,637
16	955	1,194	1,432
18	849	1,061	1,273
20	764	955	1,146
22	694	868	1,042
24	637	796	955
26	586	733	879
28	546	683	819
30	509	637	764
32	477	596	716
34	449	561	674
36	424	531	637
38	402	503	603
40	382	478	573
42	364	455	546
44	347	434	521
46	332	415	498
48	318	397	477
50	306	383	459
52	294	369	441
54	283	354	425
56	273	341	410
58	264	330	396
60	255	319	383

Although there are a great number of grinding wheel shapes, the plain disc form, Fig. 117, A, predominates, because of its suitability to so many classes of work. It is made in various sizes and proportions, an indication being given in succeeding figures. B is a very thin style, employed for cutting off, and for certain classes of cutter grinding. In Fig. 118 a selection of profile edges of disc wheels is given, as used for ordinary grinding, cutter grinding, saw sharpening, and gulleting, &c., angles and curves varying considerably. Coming back to Fig. 117, C and D are small wheels or rollers used for internal and pin grinding. E is a recessed wheel, employed for grinding down shoulders and collars on cylindrical work. F is also for this class of operation, the shape causing the wheel to stand out sideways from its mounting. G is coned for cutter grinding, H and J are cup wheels also for cutter grinding, their off-set enabling angles to be reached with facility. K, L, M are cup wheels, the important feature of which is that the speed of rotation need not be altered, as in the case of the disc wheels, because the wear taking place on the faces *a* causes no diminution in diameter, the slight amount in K excepted. These are employed principally on tool grinders, and surfacers. N is a cylinder, also operating by the face *a*, but requiring a different mounting to grip it by. Variations are often made in disc, and cylinder, and cup wheels in the introduction of dovetail or vee shapes, which hold the wheels more securely, in special mountings.

The mounting of wheels is done in diverse ways. The plain disc is put on a spindle, Fig. 119, A, the lead bush in the wheel hole being an easy fit on the spindle, and clamping takes place through washers and nuts; rubber, paper, or card discs (shown black) being interposed to produce a soft grip. Economy is often practised by making a much larger hole in the centre of the wheel, where the emery is really not wanted, and using shouldered washers, B. Another device to save material is to occupy the centre with a metal portion, into which the emery or other abrasive is moulded, C and D. Off-setting of the wheel is adopted in certain grinders, such as at E, where the mounting consists of a cupped flange, which has the effect of bringing the wheel nearer the centre of the head, avoiding overhang. The wheel is clamped by a ring closed up with set-screws. F is the mounting for a wheel mentioned previously, the dishing bringing the face out clear, to operate on shoulders without fouling the nuts. A peculiar type of wheel employed for heavy surfacing is made up of slabs or sticks of abrasive, of segmental form, clamped in a ring with spaces between which permit the free escape of par-

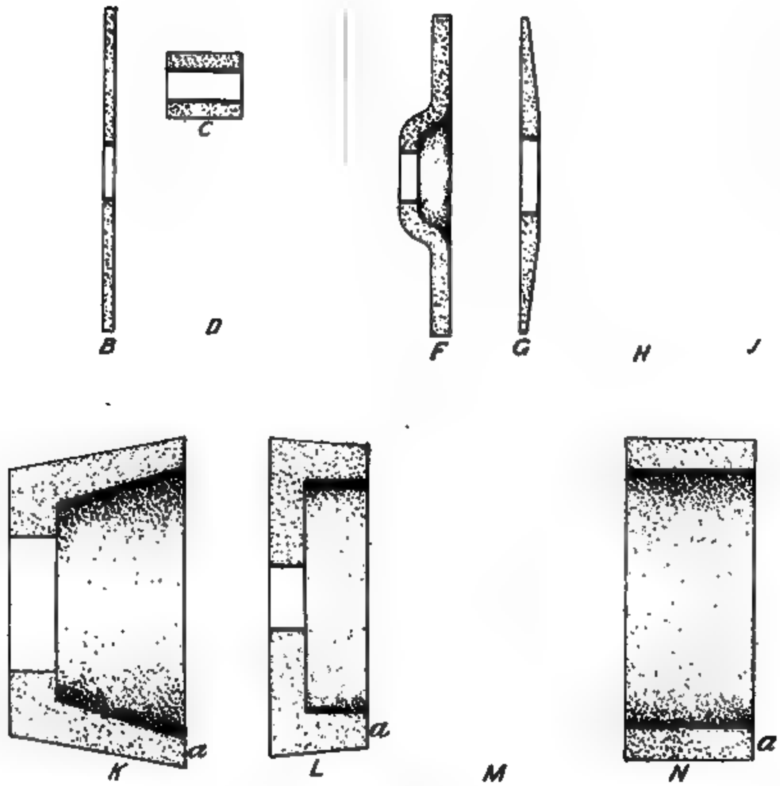


Fig. 117.—Grinding Wheels.

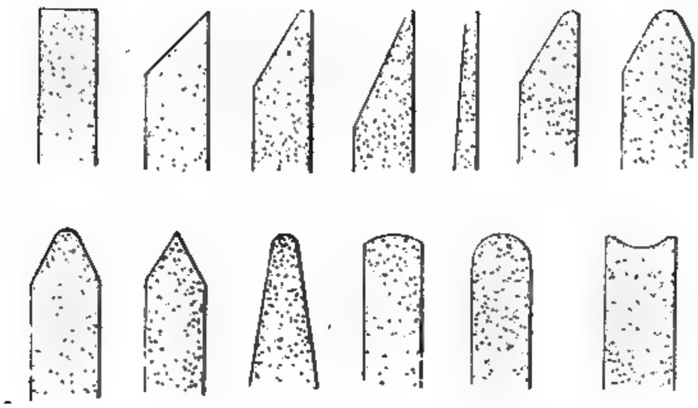


Fig. 118.—Shapes of Disc Wheel Edges.

ticles. These wheels are used to a considerable extent for such work as armour-plate grinding.

A noticeable feature of wheel mounting in recent years is the increase in the safety devices which prevent the pieces from flying should fracture occur. A modification of style B, Fig. 119, is made with the flanges dished inwards to grip a dovetail surrounding the hole on both sides. Or the flanges may go right up the faces, as in Fig. 120. A plain bevelled washer, Fig. 121, is also effective, either as shown, or duplicated on each side. Cup wheels are protected by a split casing such as in Fig. 122 which bonds the periphery, being clamped with a nut on a tapered thread. As the face of the cup wears, the countersunk screws let into the mounting are loosened, and the casing slid backwards. The cup is gripped against the mounting by the ring, and three set-screws. The cylinder N in Fig. 117 is held in a similar manner, except that the only grip is by the encircling casing being squeezed inwards.

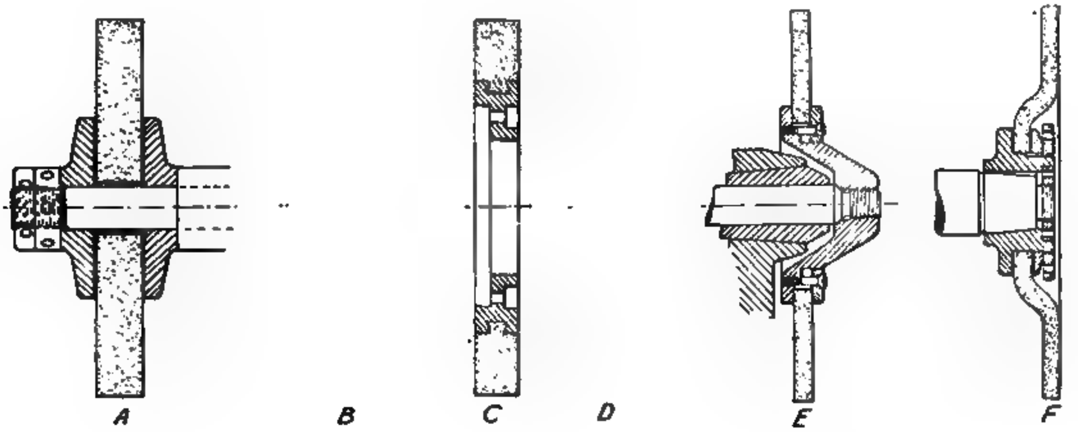


Fig. 119.—Grinding Wheel Mountings.

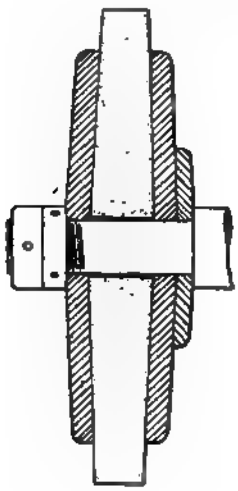


Fig. 120.—
Coned Safety Mounting.

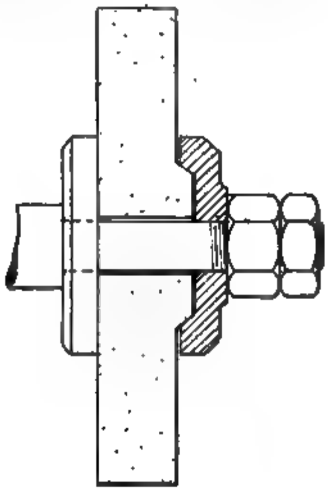


Fig. 121.—
Bevel Washer Safety Mounting.

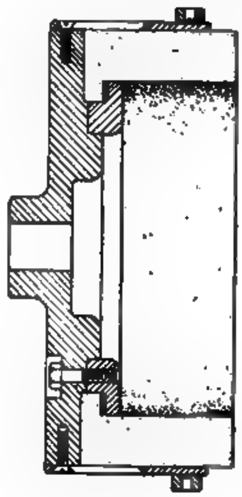


Fig. 122.—
Cup Wheel Mounting.

Grindstones.—These are either natural or artificial. The first are obtained from the

millstone grit, from Newcastle, Derbyshire, and in the vicinity of Sheffield. They are a silicious sandstone, the silica amounting to over 80 per cent. This with carbonate of lime and oxide of iron are the principal elements. Too much silica produces hardness, too much of the other ingredients renders the stones too soft. A hard stone glazes quickly, a soft one soon wears away. The fineness or coarseness of grit, however, exercises influence, and between these stones a large range in grade is obtainable. Artificial stones are formed by compression, with a cementing material. Their great advantage is homogeneity, which is difficult to secure in large natural stones. Grindstones are run at from 1,000 to 2,000 feet per minute; artificial stones may be run at higher rates, not exceeding about 4,000 feet. Water is used. Many grindstones are mounted with tool holders, and slide rests. These are used now to a much less extent than formerly, because of the rivalry of the emery and other grinding wheels.

Grindstone Truer.—The commonest method of truing up grindstones which have worn irregularly is to use a square bar of steel, held at an angle, somewhat like a turning tool, so that the high parts of the stone are removed. The bar must be constantly turned about to present fresh cutting edges. If the stone is situated near machines, cloths must be hung around it to prevent the dust from flying and causing damage.

Another device is to use a circular cupped steel disc held in a frame having a slide, so that the disc can be traversed across the stone as it cuts the latter away.

Gromet, or Grummet Washer.—A washer used to put under the heads of bolts in cast-iron water tanks. It is a strand of rope, tar-twine, or spun yarn, twisted into a ring.

Grooving.—The wearing of open cracks in certain parts of boiler plates due to alternate bending and straining movements. The remedy is to provide for elastic movements in the plates, which will thus accommodate themselves to the bending action without developing cracks. This is the object of substituting flanging for angle rings, and for providing breathing space around gusset stays. Grooving is hastened by the acids in the water attacking and wasting the cracks. *See* **Boiler Explosions, Gusset Stays.**

Ground.—A common prefix. A ground plan is the plan of a building, or machine foundation, or base. Ground wheels are the travelling wheels of portable cranes, of goliaths, and gantry cranes.

A ground line is the datum line or level which corresponds with the plane of insertion of a crane post into its base plate. It is the fulcrum where the intensity of bending stress is greatest. The post is *encastre* in that plane.

Grout.—A liquid mortar, cement, or concrete used for filling cavities in masonry or concrete work, and for effecting union between concrete blocks. It may be used loosely, or in bags.

Groynes.—Artificial barriers erected on the coast to prevent encroachments of the sea. Their particular function is to promote the accumulation of shingle, and so protect the bases of cliffs from destructive wave action. The height of groynes is therefore of much importance, since this must not be so great as to prevent the shingle being washed over, nor so low as to allow it to be washed back. The height of groynes is increased as the material on the protected beach accumulates. So that a groyne is a thing of growth, something which must be maintained if absolute protection is to be afforded to the menaced coast. To whatever extent the shingle accumulates, its backward movement must be arrested by the groyne, without impeding the movements of the water. It will be noted that shingle is the best protection to a coast, and that the object of the groyne is to conserve the shingle.

The direction, or *lay* of a groyne must be determined by the prevailing direction of the most dangerous winds. And if destructive winds blow from opposite directions, the groyne must be strutted or tied.

The construction of groynes is varied in a good many ways. Piles in all cases must be driven in the first place. These are often of timber, sometimes of iron or steel. When the latter are employed they are generally old rails, utilised. They are driven 10 ft. or more below the level of the beach, depending on the nature of the soil, and spaced from about 7 ft. to 10 ft. apart. The spaces between the piles are covered on the windward side with timber planking, and this forms the main screen. To

this, land struts are generally attached at a good angle, resting on shorter piles well below the level of the beach. The usual fastenings adopted in heavy carpentry are employed, as bolts, joggle pieces, straps of various kinds, knees, and waling pieces.

Another type is the box groyne, in which double rows of piles and timbers enclose a

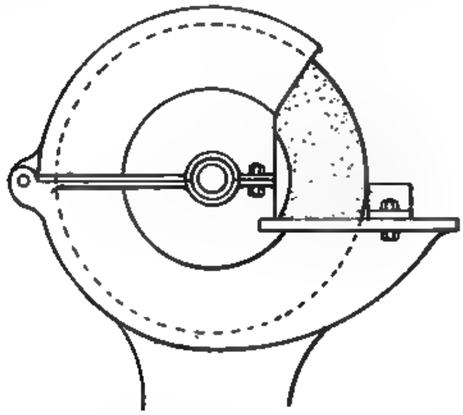


Fig. 123.—Cast-Iron Guard.

space filled with boulders. The sides taper, and the seaward end is pointed to divide the waves.

Groynes should extend from the high-water mark of spring tides to a few feet below low water. When more than one groyne is used, they should be set from 50 ft. to 100 ft. apart, between which the shingle accumulates. They follow the slope of the beach. The tops of groynes should be connected with a permanent wall. Groynes have also been used to afford protection to cofferdams used as sea barriers, erected to exclude the water from docks in course of construction. As they favour the accumulation of gravel, and shingle, or sand, they thus reduce the force of the sea against the barriers.

Grub Screw.—A headless screw.

Guard Rails.—Short rails placed parallel with and on the inner sides of the outer rails of a crossing. These with the wing rails that flank the crossing act as a check to any tendency of the wheels to take the wrong gap in the crossing.

Guards.—Specifically, protective coverings partly surrounding wheels that rotate at high velocities, and reciprocating parts. The most common are those which enclose toothed wheels, emery wheels, and saws. *See* **Accidents—Prevention of, Saw Guards.** The illustrations given here are those of guards for emery wheels. A guard of cast iron is seen in Fig. 123. It is hinged to the trough casting to permit of renewal of the wheel, or for cleaning out, repairs, or inspection. Fig. 124 is a guard of sheet iron or steel, with the obvious advantage that a flying wheel will not fracture it, an accident which is liable to happen when guards are of cast iron. Fig. 125 is a wrought-iron guard, the upper part of which is tied to the lower by the curved pieces at the sides. Many corrugated hoods are now used which have the advantage of adjustability, closing round the wheels as the latter wear.

Gudgeons.—The old term for journals, and now falling into disuse except for the pins in crossheads, and in the beams of beam engines.

Guide.—A common prefix. Guide bars are **Slide Bars.** Guide irons are used for sweeping up curved cores, *see* **Bend Moulding.** Guide pulleys alter the direction of belts, *see* **Belting.** A guide screw is the **Lead Screw** of a lathe. A guide screw stock is the Whitworth stock, illustrated under **Dies.**

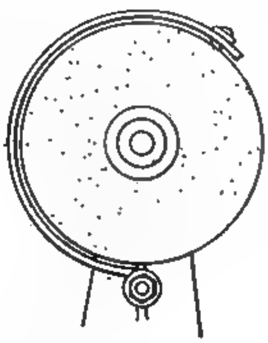


Fig. 124.—Sheet Metal Guard.

Guillotine Shears.—A special type of double-ended shearing machine used for cutting up puddled bars and slabs for reheating and rolling in iron mills. Also long-bladed shearing machines for sheet metal.

Gulleting.—Grinding or filing out the roots of saw teeth of that shape. There are numerous machines designed for this work. *See* **Saw Sharpening Machines.**

Gullet Teeth.—Saw teeth which have concave instead of angular roots or gullets. They give freedom for the sawdust and are therefore used largely in coarse ripping, circular, and frame saws.

Gumming.—Used in the same sense as gulleting or deepening the teeth of saws. Also relates to the thickening of some kinds of lubricating oils.

Gun-Cotton.—The first step in the discovery of gun-cotton dates back to 1832 when Braconnot, a Frenchman, discovered that the action of nitric acid on starch yielded a highly combustible product. In 1838 Pelouze experimented with cotton, and in 1845 Schönbein, a German chemist, showed that gun-cotton could be satisfactorily prepared by immersing cotton in a mixture of strong nitric and sulphuric acids. Repeated explosions and the failure of gun-cotton cartridges with which the Austrian artillery were supplied in 1852 resulted in a temporary check to its manufacture. The factory of Messrs Hall & Sons at Faversham was closed after a disastrous explosion in 1847, and one under the supervision of General von Lenk near Vienna in 1865. But the investigations of Sir Frederick Abel in England eventually led to a safe process of manufacture, and a factory was established at Stowmarket in Suffolk on the site of the present works of the New Explosives Company.

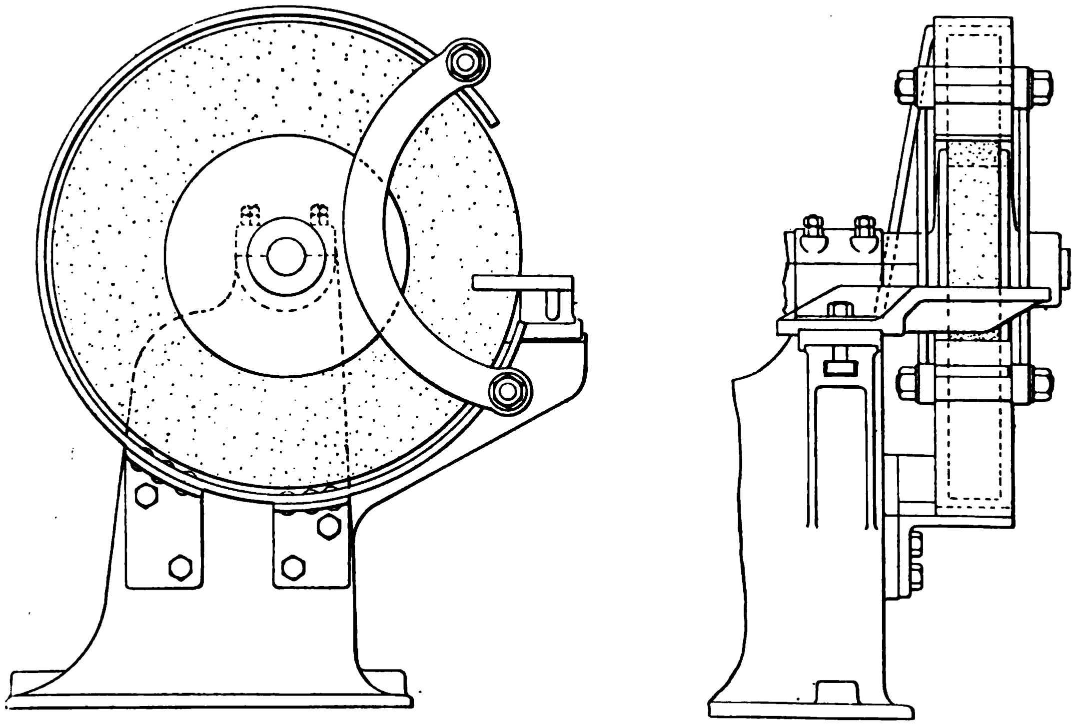


Fig. 125.—Wrought-Iron Guard.

The process of manufacture is as follows:—Cotton waste from the mills is thoroughly purified by combing, boiling with alkalies, removal of foreign substances by hand picking, and loosening lumps and knots in a teasing machine. It is then cut into short lengths, dried, and placed in air-tight iron vessels ready for removal to the dipping house, where the cotton is immersed for a few minutes in the mixed acids. The formation of gun-cotton is represented by—

$$\underset{\text{Cellulose.}}{C_6H_{10}O_5} + \underset{\text{Nitric acid.}}{3HNO_3} = \underset{\text{Gun-cotton.}}{C_6H_7 3(NO_3)O_2} + \underset{\text{Water.}}{3H_2O}$$

The water formed reduces the strength of the

nitric acid, and to avoid this, strong sulphuric is added to absorb the water. One part of nitric is used to three parts of sulphuric. After removal from the dipping house the nitrated cotton is squeezed to extract the excess of acid, placed in the steeping pit for twenty-four hours, and freed from acid in a centrifugal extractor. Final washings serve to remove all traces of acid. It is next pulped, washed, and dried, and then either moulded into slabs or discs under hydraulic presses, or left in the loose state.

Gun-cotton is in appearance similar to ordinary cotton. Its most remarkable property, and one which has made it invaluable for military and naval use, is that it may be kept wet for indefinite periods without loss of power. Containing 18 to 20 per cent. of water, it may be stored or transported without danger, being detonated only by the explosion of a dry primer with which it is in contact. In this way it is used for submarine mines, torpedoes, and shells. It is quite uninflammable when wet—the British Government authorities set fire to a shed containing a ton of wet gun-cotton, but it merely smouldered away as it became dried. Gun-cotton is also used in the dry state and may then be detonated by a severe shock, or by heating to about 170° Cent. (338° Fahr.). Unlike gunpowder it leaves no residue and produces no smoke. Its action is also much more rapid than that of gunpowder.

Some interesting tests carried out by the New Explosives Company illustrate the marvellous destructive power of gun-cotton. A 6-inch shell was burst inside a closed chamber of wrought iron whose thickness was 7½ inches and total weight 6½ tons. The shell was of cast steel of a total weight of 119½ lb. The weight of the wet gun-cotton charge was 6 lb. 9 oz., and the primer 300 grammes. The force of the explosion burst the coil open, and the fragments collected amounted to 2,122 pieces.

Gun-cotton also enters into the composition of other explosives, powders, and perfectly harmless articles of commerce. Blasting gelatine is a solution of gun-cotton in nitroglycerine: tonite contains 52·5 parts of gun-cotton and 47·5 of barium nitrate; potentite is composed of gun-cotton and saltpetre; soluble gun-cotton enters into the composition of smokeless powders; celluloid is a mixture of the explosive and camphor; artificial silk is prepared by dissolving gun-cotton in a mixture of ether and alcohol; and many spirit varnishes, lacquers, artificial leather, and rubbers also contain gun-cotton as an essential component.

Gun-Metal.—An alloy of copper and tin only. But see **Bronze**. Copper with about one-ninth its weight of tin was used for ordnance, hence the term gun-metal. It is often called *hard brass* by engineers, to distinguish it from the soft brasses which contain zinc and lead. Proportions of tin and copper in pure mixtures vary, but 89 or 90 of copper to 11 or 10 of tin is a usual proportion for engineers' work. If a very small proportion of zinc is added, the alloy mixes better, and the colour is improved. The copper is melted first, and tin or zinc added. Gun-metal was used almost exclusively for bearing purposes until the introduction of phosphor-bronze, aluminium, Delta, and other alloys which often have greater strength, toughness, and durability. See the various heads under which these alloys are noted.

Gunpowder is a mixture of saltpetre (nitre, or potassium nitrate, KNO_3), charcoal, and sulphur. The proportions vary for different purposes and in different countries. In Great Britain gunpowder is generally composed of 75 parts nitre; 15 charcoal; 10 sulphur. The chemical action which occurs when gunpowder is exploded is a highly complicated one, and can scarcely be represented in the form of an equation. Heat liberates the oxygen of the nitre and this combines with carbon to form carbon dioxide; the nitrogen is also set free and sulphur unites with potassium. It is to the sudden evolution of these gases—increased still more in bulk by the high temperature—that the explosive power of gunpowder is due.

Only the purest ingredients are used, the quality of the charcoal in particular being important. Dogwood, alder, and willow are generally used. The three constituents are separately pulverised, then mixed in the desired proportions and incorporated in a wet state. Sometimes sulphur and charcoal, or sulphur

and saltpetre are pulverised together. The mixture is next compressed into cakes, which are then broken up and granulated in a machine, the powder being classified by means of sieves, with meshes of different size. After dusting, the grains are glazed in a revolving barrel, their surfaces acquiring a polish owing to the friction produced. The powder is finally dried in a stove and dusted once more.

Small quantities of gunpowder merely burn away when ignited; large quantities explode. It has been estimated that a kilogramme ($2\frac{1}{5}$ lb.) of gunpowder develops in a hundredth of a second over 1,500,000 foot pounds of energy, as compared with 7,250,000 foot pounds in a fifty-thousandth of a second generated by an equal weight of dynamite. The explosive force of gunpowder is roughly about 18 tons per square inch. In quarrying operations the charge per cubic yard of rock varies considerably according to the nature of the rock, the quantity necessary lying between $\frac{1}{4}$ and 5 lb. But the use of gunpowder has been largely superseded in late years by the introduction of more powerful and smokeless explosives.

Guns.—The gun is very similar in principle to the gas engine, and in construction the gas engine resembles some of the earlier forms of guns to a large extent. There is the same barrel closed at one end, and the same ignition of an explosive in the closed end of the barrel, and the same forcing of what is virtually a projectile in both cases violently away from the closed end. In the gun, however, even in the very early forms, the barrel is longer than that of the gas engine, while in the latest modern forms it is very many times as long. In the gun the shot or shell takes the place of the piston of the gas engine, but in place of passing the energy that is delivered to it on to a crank shaft, the energy is stored in the projectile itself, which is driven to a great distance, and the energy is delivered on impact by the projectile, in the process of destruction.

The early smooth-bore guns consisted of either an iron or gun-metal casting, with a cylindrical bore from the muzzle to the breech, the latter being chambered as far as was possible for the reception of the powder charge. The gun was roughly divided into two portions of about equal weight, by the trunnions, upon which it was suspended in its carriage. The trunnions were virtually horizontal axles, projecting from the sides of the gun, and resting in bearings, termed trunnion sockets, in the carriage. The rear portion of the gun was always much shorter than the front portion, and hence the trunnions were nearer the breech than the muzzle. The only opening to the powder chamber, except by way of the muzzle, in the old muzzle-loading guns was a small hole drilled from the top of the gun, through which the charge was pricked by a pointed wire provided for the purpose, by the captain of the gun, previous to firing. The charge in those days was loose gunpowder, enclosed in a bag, and it was forced home by a cup shaped rammer, entered through the muzzle. The projectile was a spherical mass of iron. When cast solid it was called a round shot. For a shell it was cast with a cavity inside, in which a small charge of powder was placed, the charge being ignited by a fuse, either when the shell struck an object, or at a certain time after it had left the muzzle of the gun. When the charge exploded the iron ball was split into a number of pieces. There was another shell in those days known as the shrapnel, in which the cavity in the iron ball was made sufficiently large to hold a charge of powder, and a number of small iron balls. When the charge exploded the shell was broken up as before, and the small iron shot scattered in all directions.

The old smooth-bore gun, however, was practically useless against armour, and its firing was also very inaccurate. It was necessary, in order that the shot should be rammed home with comparative ease, and with speed, that it should be reasonably loose in the bore, hence there was a considerable amount of what artillerists call *windage*. In any gun the projectile is forced out through the muzzle, and to its destination by the rapid generation of gas when the powder is consumed, aided by the liberation of a very large quantity of heat, the hot gases forcing the projectile out in front of them, in their effort to expand. Where there is windage, a certain portion of the hot gases escape between the projectile and the

walls of the gun. In addition to these gases not being available for driving the shot forward, they tend to cause an erratic motion of the projectile within the bore, up and down, and from side to side, with the result that the last push the projectile receives before leaving the muzzle of the gun very largely influences the direction it takes in its flight. All of these considerations led to the development of the elongated cylindrical projectile, and to the rifled gun.

Rifled Guns.—All modern guns are rifled, and the projectiles are all cylinders whose length is from twice their diameter upwards, and the front of all projectiles is formed into a point, the front portion approximately assuming the form of a cone. In the early rifled guns there were only a very small number of grooves, three being the favourite number, and the projectile was kept in the grooves by studs placed at intervals in its length. The 7-in. early muzzle-loading rifled shot, for instance, had three sets of studs, each set consisting of two. The early rifled guns were principally muzzle-loading, though the very earliest, those brought out by the late Lord Armstrong, were rifled; but the arrangement for closing the breech of the breech-loading Armstrong gun of those days was not as perfect as that of the present day, and accidents occasionally took place; hence, for a very long period, the muzzle-loading rifled gun held the day. The march of events, however, has practically obliged artillerists to adopt the breech-loading gun, the principal factors in determining this being, the increasing length it was necessary to give to the gun, and the increasing accuracy it was also necessary to give to the bore and the flight of the projectile. In the early muzzle-loading rifled guns there was the same complaint of windage as in the old smooth-bore, though not to the same extent. The rifling of the rifled gun is intended to give a rotating motion to the projectile as it passes through the bore, in addition to the motion of bodily translation, and the projectile is intended to maintain its two motions, rotation around its long axis, and direct motion forwards, point first, after it leaves the gun. In order to accomplish this, the grooves of the rifling are given a spiral twist, and the projectile having to follow the twist acquires the rotary motion before it leaves the muzzle. With muzzle-loading guns, however, in loading the gun, the projectile had also to be given a twist in passing down the bore, similar to, though reverse in direction, to that which it received on being expelled, and this rendered a certain amount of loose fitting between the studs on the projectiles and the grooves in which they ran necessary, hence the windage. In the modern gun the base of the projectile is fitted with a copper ring which cuts its own way into the grooves as it is forced into the bore, and the projections formed in the copper ring are sufficient to keep the projectile in the grooves, and to give it the necessary rotating motion. In addition, in the modern gun, the amount of twist of the spiral grooves is gradually increased as the projectile passes from the breech to the muzzle, so that the amount of rotation is also increased.

Construction of Modern Guns.—All modern guns are constructed on certain lines. In all there is an inner steel tube, known as the "A" tube, turned and bored from a solid steel ingot of the very best and toughest material obtainable. In the muzzle-loading gun, one end of the tube is closed, and when it has been fixed in the gun a large solid screw, known as the Cascable screw, is butted right up against it, the Cascable being screwed into the mass of the breech of the gun. In the breech-loading gun, both ends of the tube are left open, the breech being closed when the gun is loaded by a breech-block, as will be explained. One of the great problems that artillerists have had to solve in the construction of modern guns has been, the provision of sufficient strength to withstand the enormous strains to which certain portions of the gun are exposed when the charge is fired. The greatest strains necessarily are those in the neighbourhood of the explosive chamber. Though the firing of a gun and the expulsion of the shot from its muzzle are apparently instantaneous, a certain definite time elapses before the projectile moves, and during this time the gas which is being generated, and which is exposed to the heat liberated, is exerting enormous force upon the chamber in which it is held. Hence it is necessary to provide the greatest strength of the gun in the neighbourhood of the breech,

and the strength decreases as the muzzle is approached. There are two methods that have been adopted for building up the portions of the guns outside of the steel tube described, so as to provide the necessary strength in the proper proportion. In the earlier form, of which a large number are still in use at the present day, steel rings of different thickness were slipped over the "A" tube, one over the other in the rear parts. The gun was built up in this way, only one or two outer rings being placed over the *chase*, that portion in the neighbourhood of the muzzle, a greater number being placed in the neighbourhood of the trunnions, and a still greater number over the breech, the whole being locked together by being shrunk one upon the other, and by joints somewhat similar to the well-known bayonet joint, so that when the gun was fired, the joints tended to close up rather than to open. In the other method the whole of the gun outside of the "A" tube is formed of wire. The tube is put in a lathe, and the wire, which is rectangular in section, 0·25 in. wide and 0·06 in. deep, is wound on it, layer upon layer, just as the wire coils of an electro-magnet are wound, but the muzzle portion only receives a small number of layers, fourteen in some of the larger guns, while the breech in the same guns receives as many as ninety-two, the intermediate portions receiving proportionate numbers. In some guns the two methods are combined, a certain portion of wire is put on and steel rings are shrunk over them. It will be seen that the method of coiling wire in the manner described should give the very best results, as the strain will be in the direction of the length of the wire itself, the breaking strain of the wire employed being from 90 to 100 tons per sq. in.

The breech-block used in British guns is an adaptation from the French, and is very efficient and very simple. The breech of the gun is bored and screwed, and a screwed breech-block is fitted to it. After fitting, the surface of the breech-block and the inner surface of the screw of the breech are divided into six or eight sections longitudinally, three or four of the sections of breech-block and breech being planed or slotted smooth, the portions which are made smooth in the breech being opposite to portions of the screw which are left in the breech-block. The breech-block is entered into the breech by fitting the screwed portions into the plain portions, and the breech is locked by giving it a sixth or an eighth of a turn, according to the amount that is cut away, and it is further locked by levers on the outside. It is also arranged that the gun cannot be fired unless the breech-block is quite home, and is properly locked. The possibility of doing this was the great fault in the early Armstrong. The breech-block is hung from a hinge at the side of the breech of the gun, and when loading is to be done, it is first unlocked, then withdrawn, then turned on one side out of the way, and the powder chamber and bore are then exposed.

Loading Modern Guns.—As the weight of both projectiles and powder have increased so enormously with the size of the guns, it has been necessary to provide mechanical means of handling them. One arrangement is as follows:—There is a vertical shaft from the neighbourhood of the ammunition chamber, leading to the rear of the gun. In this shaft a small cage with three decks runs up and down; small carriages running on rails from the ammunition chambers, and magazines are run on to the cage. The upper deck of the cage carries the projectile, and the lower decks the two halves of the powder charge. This it will be understood is for very heavy guns. Where the charge is not so large as to be necessary to be divided into two, there is only one deck for the powder charge. On arrival at the rear of the gun, the breech being open, the cage is placed in line with the breech, and a hydraulic rammer from behind forces the projectile through the breech, and into its place in front of the powder chamber. The cage is then raised till the first portion of the powder charge is opposite the breech. This is then pushed into the powder chamber in the breech, the third deck raised and its portion forced into the chamber, the breech closed, the rammer returned to its place, and the cage returned to the ammunition chamber. In the old days, after the gun was fired, it was sponged by means of a sort of mop at the end of a long rod, the mop being well wetted. It is necessary

to perform some operation of this kind, in order to clear out of the gun any possible burning fragments that may remain, and that would ignite the fresh charge when the gun is loaded. In the modern gun there are two methods of performing this operation. With the breech-loading gun a small hose with a nozzle at the end, and having a pump near, is employed to thoroughly swill out the powder chamber, and as much of the bore as can be reached, and is likely to hold any burning fragments. In the muzzle-loading guns that are still in use, the sponging is performed by the hydraulic rammer. The head of the rammer contains a quantity of water which is released by a valve that opens as the rammer is pushed home into the powder chamber. In another method of loading, a loading carriage is provided either at the breech or at the muzzle of the gun, to which it is brought by hydraulic or other convenient mechanical power, and the hydraulic rammer pushes the projectile and the charge successively into the gun by the breech, or the muzzle, as may be required.

Controlling the Motions of the Gun.—In the early muzzle-loading rifled guns, the recoil of the gun was taken up by what was called a "compressor," consisting of sets of long thin plates, fixed in the slide upon which the gun-carriage was mounted, with other plates attached to the gun-carriage itself, and fitted between those carried by the slide. The guns of those days were mounted on short metal carriages, very similar in form to the old wooden carriage of smooth-bore guns, the carriages being mounted on long metal slides, the slide itself being trained forward or aft by running on metal rollers formed in arcs of circles on the deck or floor, the port being the centre. When the gun was fired, a trip arrangement on the slide caused a lever to come into operation, which squeezed the whole of the plates up together, producing a good deal of friction, and absorbing the energy of the recoil. The guns of those days also had the old rope breeching which prevented the gun from recoiling beyond a certain distance. In the modern gun all that has been done away with. The gun recoils against the resistance of a hydraulic buffer, consisting of a cylinder with a piston moving in it, the cylinder containing oil or other liquid which is forced through holes in the chamber into another vessel. In the latest form there are two hydraulic cylinders, one on each side of the gun, united by a transom in front, and together forming the carriage of the gun. The piston of one cylinder is arranged to force the oil backwards, the piston of the other cylinder to force it forwards, the two cylinders being connected by a pipe, the result being that a considerable friction is set up, this absorbing the recoil of the gun.

The hydraulic arrangements are various, but all on certain main lines. There is the usual tank from which the water is taken, and to which it returns when it is allowed to run away, after having done its work, and there is the usual compression tank from which pressure is taken to the piston, or other arrangement. The gun is elevated by a hydraulic cylinder and piston, it is trained in the same way, and the turret, when the gun is carried in one, is moved by hydraulic cylinders. The turret is locked in the loading position by bolts which are worked by hydraulic pistons, and so on. The hydraulic rammer consists of a number of tubes, one inside the other, each having a head piece. When the pressure is applied, the tubes are forced out, one after the other, to the full length of the apparatus, and when the loading is done, they are forced back as the water is allowed to run away. Electricity is now gradually displacing hydraulic machinery for everything in connection with guns. Electric motors are geared to train the gun and the turret. They are used for working the ammunition hoist, for elevating the gun, for loading, and for all the arrangements necessary, the motor and its gearing taking the place of the hydraulic cylinder. For several portions of the work, ramming the shot and charge home for instance, the electric motor is not so convenient at first sight as the hydraulic ram, but it is steadily taking its place.

Quick-Firing Guns.—Quick-firing guns are similar in nearly every respect to the others, with the exception of special arrangements for throwing out the empty cartridge, and for opening the breech, ready for the receipt of a

fresh charge, and a fresh projectile. Spiral springs are brought largely into use for ejecting the old cartridge, and there are a number of special details in connection with the guns of different patterns, from the Maxim, upwards, in which the recoil of the gun is employed to perform the work of ejecting the old cartridge, and inserting a new one, firing it, and so on, for which there is not space here to deal with.

Gusset Stays.—Plated stays used for connecting the areas of the flat ends of Lancashire and Cornish boilers above the furnace flues, to the shell. They are united to the first and second shell plates, and to the flat ends with angles. Formerly they were brought right down to the furnace flues, which made no provision for necessary elastic movements, and so caused grooving. Now a space of about 9 in. is left between them to afford a breathing area. Formerly as many as seven stays were sometimes used in these boilers. In present practice there are only five above the furnace flues in Lancashire boilers, and one below, and they are so set out as to allow some movement of the plate in the intervals, and equalise the stresses. The stays are thin, and riveted with double angles to put the rivets into double shear.

Let a = area to be supported by the stay,

p = pressure to be borne by each square inch of cross section, say 7,000 lb. per sq. in. for steel,

P = boiler pressure in lb. per sq. in.,

d = depth or breadth of stay at the narrowest part,

t = thickness of stay.

Then :—

$$p = \frac{a \times P}{d \times t},$$

$$d = \frac{a \times p}{P \times t},$$

$$t = \frac{a \times p}{P \times d}.$$

Gutta-Percha.—The concreted or hardened juice from certain trees found chiefly in the Malay Peninsula. It is employed principally as an insulator for cables, for driving belts, &c., being applicable to many purposes for which india rubber is employed. It is, however, lighter and more tough than india rubber. Commercially it is sold in the form of sheets, tubes, bands and cords, thread, and tissue.

Guys.—Members that support the top end of a mast or pole, as in derrick cranes, sheer legs, &c.

Guttering.—Light castings for catching the rain water from roofs; made in cross sectional capacities to carry off maximum storm water from roofs of different areas; and in shapes both plain and ornamental. Gutters have one vertical face when they are attached to outer ridges of roofs, or two bevelled faces when they lie in the angles of adjacent roofs. They are cast in lengths suitable for their sectional dimensions, and are bolted together with flanged ends, or with socketed and spigoted ends. Blank ends are cast or bolted in.

Gutter castings are very thin; from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. Being open on one side, they curve in cooling. Their patterns are therefore bent in the opposite direction, or concave on the open face. Being flimsy they are generally moulded from metal patterns, and rammed on joint boards. The metal is very grey and open, to run freely.

Guttering is made also of sheet steel, with the edges stiffened by beading.

Gyration, Centre of.—Is such a point, in a body oscillating like a pendulum, or revolving round an axis, that if the entire weight were concentrated at it, the same angular velocity would be imparted to the body by a force acting at a certain distance from the axis or point of suspension as when the weight is not concentrated. The distance between this point and the point of suspension or the axis, is the radius of gyration. *See* **Moment of Inertia.**

Gyroscope.—An instrument by which the course of a torpedo or submarine boat is controlled. The essential element is a small heavy wheel rotating a very high speed, 2,000 revolutions or more per minute. It is suspended on gimbals. At such a speed the tendency is to resist any forces imposed upon it from without tending to change its axis of rotation. Instead therefore of responding readily to such forces, it is made to control the movement of the vessel in which it is enclosed, through a motor, and rudders. Any initial change of movement of the vessel is neutralised by the inertia of the gyroscope, acting through the delicate mechanism of the motor just named.

H

Hack Hammer.—A cross-pane hammer with a chisel-like edge used in rough dressing or *hacking* of grindstones, previous to turning them.

Hack-Saws.—The metal hack-saw owes its widespread use to the introduction of the hard blades, which are used until worn out, and then thrown away; previous to this the soft style, which could be filed up when dull, held a limited field, for odd cutting-off work. Now there are enormous numbers of hard blades employed, both in hand frames and in machines. The pitch of teeth varies from 10 to 30 per in., the finer classes being used for cutting tubing, in which coarsely-pitched teeth would hitch and break. Lengths of blades range from 6 to 21 in.

The hand frame is a simple affair, of bow shape, with a couple of eyes between which the saw is strained, by a screw contained in the farther end, or formed in one with the handle. Some frames are extensible, to accommodate different lengths of blades; others have means of swivelling the blade in relation to the bow, so that it may clear work, as when cutting down the edge of a strip, or cutting in an awkward corner.

The hack-saw machines provide means of gripping the work, and of reciprocating the blade to and fro, feeding it downwards until the piece is parted off, cutting being more rapid and truer than hand work. These machines have absorbed much of the cutting off formerly effected by the smith with sett and hammer, in a rough fashion, as well as that of the lathe types of cutting-off machines.

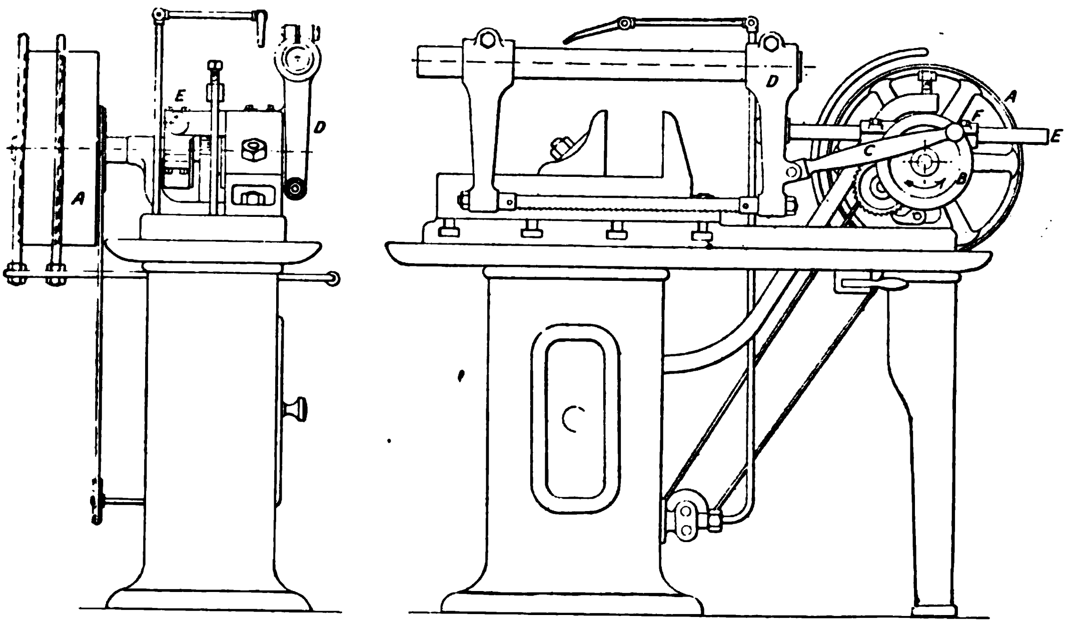


Fig. 126.—Hack-Saw Machine. End and Side Elevations. (E. G. Herbert, Ltd.)

Figs. 126, 127 illustrate Herbert's "eccentric" sawing machine; in Fig. 126 the fast and loose pulleys A drive a shaft on which the crank disc B is attached, and connected by a rod C to the frame D, which is therefore reciprocated. Guidance is effected by rods E, E, lying parallel with each other, and sliding in split bearings F, F. A detail of the eccentric device is given in Fig. 127. The object of this mechanism is to alter the angle of the saw after a certain number of strokes, and so keep it cutting on a corner instead of right across the width of work, which would mean less rapid cutting effect. The machine, in fact, imitates the action of a man when using a hand frame. The bearings F, Fig. 127, are mounted on eccentrics G encircling the main shaft. A cam H is rotated by the shaft, and acting through a lever J and pawl K moves the ratchet wheel L one tooth at each stroke of the saw. L revolves a one-toothed pinion M, which engages with a complete pinion N at each twenty strokes of the saw, and moves the eccentric G partly round, so altering the tilt or angle of the frame D with its saw. The purpose of the lever O is to support the saw frame after cutting through the work, or (in a raised position) while work is being placed in the machine. It is pivoted in F, and supported below in the cupboard base, and bears on F when the saw frame is in its lowest position, which can be adjusted by the screw in the top of O. The reason for this peculiar arrangement is to bring the support of the saw frame directly under the vice (in the base below it). If the frame were supported at any other point the position at which the saw was checked after cutting through would vary according to the position of the eccentrics.

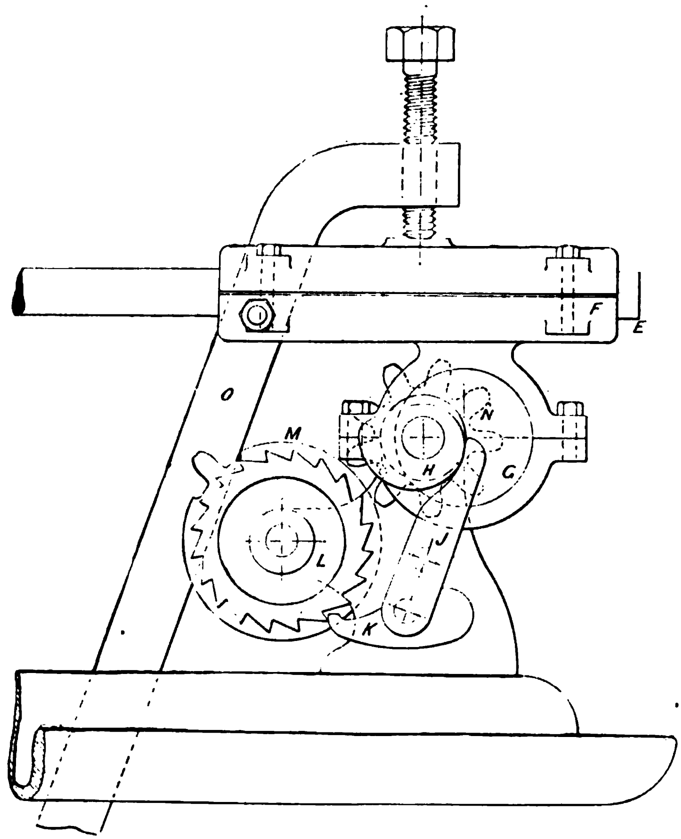


Fig. 127.—Detail of Eccentric Motion of Hack-Saw Machine.

A lubricating pump is fitted to the machine, seen in Fig. 126, and a trough around the table catches the soapy water and returns it to a tank within the cupboard base. The vice holds either round bars, or girders of any shape. Electrically-driven machines are made, having the motor underneath the table, and a special pattern is also made (originally for the Admiralty, for use on board ship) with wrought-iron standards to save weight.

In one form of hack-sawing machine, the bar being cut is rotated intermittently through a small arc, the effect being the same as the tilting of the saw.

A radical departure from ordinary machines is Thompson's, an American design, which has a coil of saw in a magazine, from which it is drawn out and clamped from time to time as wear occurs. The blade has a flexible back, the hardening being only done a little way back from the teeth.

Hæmatite, or **Hematite**.—*See* **Iron**.

Haft.—The handle of a hammer or axe or adze. Fitting a handle is termed hafting.

Hair Compass. — A drawing compass having fine adjustment.

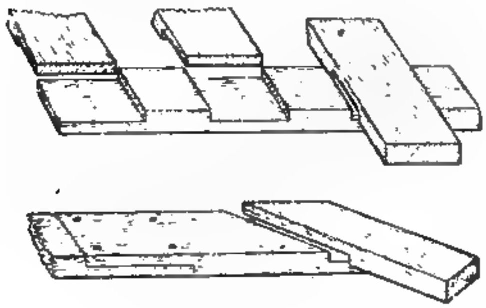


Fig. 128.—Various Halvings.

Hair Side.—The grain, or smooth side of a leather belt.

Half.—Half-crossed relates to belting that runs over pulleys arranged at right angles with each other. *See* **Belting**. Half-lap, or half-blind holes are rivet holes in adjacent plates which do not match by as much as a semi-diameter. A half-lap coupling is a box coupling in which the ends of shafts are stepped over each other longitudinally, and enclosed by the coupling. A half-lattice girder is a warren girder. A half pattern denotes either of the main portions of a jointed, and dowelled pattern. For half-round file, *see* **Files**. Half-rounds are rolled bars of semicircular section. They are either solid, or hollow half-rounds, the latter being semi-cylinders. For half-tide gates, *see* **Dock Gates**.

Half-Elevation, Plan, or **Section.**—Views which terminate at the centre of an object, one-half then being an external, the other a sectional view. These economise space in drawings. The object must be symmetrical in all respects to permit of making half views.

Half-Lap Joint, or **Halved Joint.**—A lap joint in which pieces of board are brought into the same plane by cutting half the thickness of each away for the same length as the lap extends. Examples are shown in Figs. 128, 129. Such joints are more frequently employed in pattern-making than in any other trade; mortise and tenon joints being preferable for most other work. The half-lap is not quite as neat as a mortise and tenon, but it is less troublesome to make, and in many cases is more effective in preventing the parts from warping. At the corners of framings it is stronger than a mortise and tenon, but the parts of course are always entirely dependent on the means which hold them together, and are not assisted by the closeness of their fit as in a mortise and tenon. For joining pieces end to end, a half-lap or modification of it is always the best form of joint. Half-lap joints are usually held together by screws, or, when they occur in

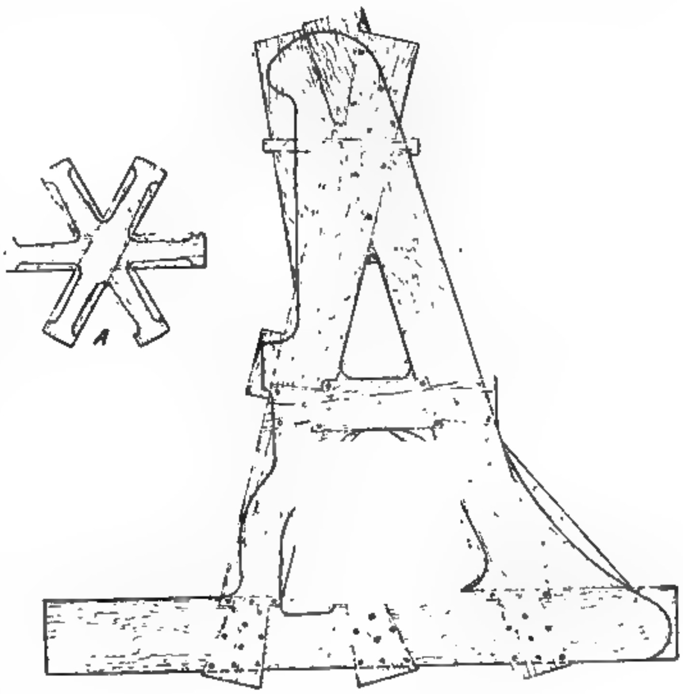


Fig. 129.—Crane Side-Frame Pattern.

heavy carpentry, by bolts. The laps are often dovetailed into each other or otherwise modified in detail, and then have to be distinguished by different names.

The great advantage of halving is the maintenance of straight grain, with strength, and freedom from shrinkage, by comparison with cutting out of the solid. It does for boards the same thing that building up in segments does for deep work of circular or curved outlines.

Examples of plain halvings are shown in Fig. 128, and dovetailed ones in Fig. 129. The latter is a good illustration of a pattern web constructed by half-lap joints, with the outlines to which it has to be cut, marked out. It is the side-frame of a crane, and the arrangement of material is such that no short grain occurs anywhere. The dovetailed key will be noticed also at the top which preserves the rather wide stuff there from curving.

At the left hand, at A, a modification of a half-lap joint is shown in the arms of a wheel, locked together by cutting a third of the thickness away from each piece.

Half-Rip Saw.—A saw between the rip, and the hand saw. It contains about 3½ teeth to the inch. It is used for rapid cutting down with the grain.

Hammer Hardening. — Elasticity and hardness are imparted to malleable metal by long continued hammering. This renders the texture more dense, but at a sacrifice of ductility. Annealing removes the effects of such hardening, just as it does in the kindred operation of drawing.

Hammer Head.—The hammer itself as distinguished from its handle.

Hammerman, or Drummer.—A smith's striker.

Hammer Marks.—The marks left by the hammers on forgings during reduction. For good appearance they are removed by flatters, or swages.

Hammers.—These percussive tools are used in all trades connected with engineering, for driving, flattening, bending, riveting, raising, &c. Cutting action is only found in the boiler-maker's scaling hammers, and in some quarrying hammers. With the exception of the copper and lead types, hammers are made of steel, or of iron, faced with steel, and hardened.

Typical wood-workers' hammers are shown in Fig. 130 with their handles. A is perhaps the most common kind, the Exeter, employed by many different trades; B is a slightly heavier pattern, used by joiners. C, the pattern-maker's type, is longer, to reach into recesses, and the handle is usually longer. This style is also made with a ball pane instead of the flat one. D is a joiner's hammer, rather heavier than B, while E is a Canterbury claw hammer, the claw being employed for drawing nails. The method of handling is different, the head being prolonged into a couple of ears which embrace the handle, and are riveted to it, thus preventing the head from quickly working loose through the use of the claw.

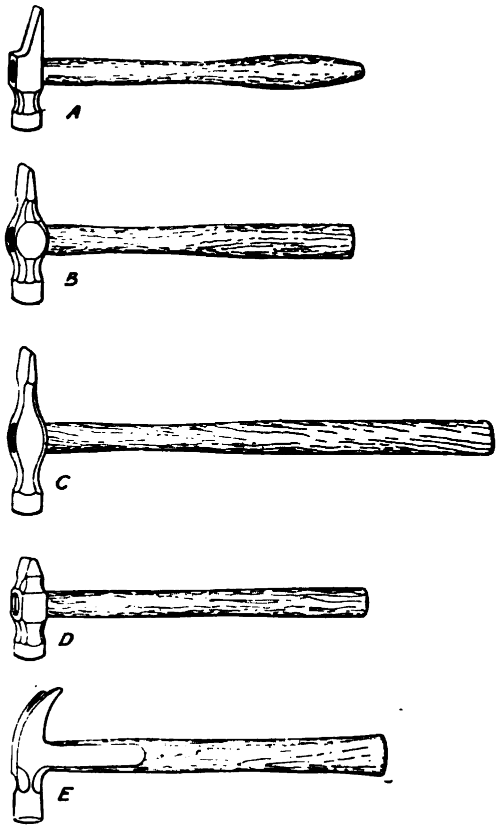


Fig. 130.—Wood-workers' Hammers.

Engineers' hammers, Fig. 131, comprise the hand and the sledge, used for all kinds of hammering, driving, riveting, &c. A, B, and C are ball pane types, differing in shape, the pane being employed for hollow work, and at the commencement of riveting. D, the straight pane, is

useful for narrow localities, which lie in line with the handle; while the two kinds of cross pane, E, F, are applied to the opposite conditions, being especially valuable for riveting close up to a shoulder or face. Sledge hammers include the double-faced G, the straight pane H and J, differing in proportions, the cross pane K, L with rounding pane, and M with ball pane. Platelayers' keying hammers N and O are long and narrow, for driving the keys of chairs in or out.

Boilermakers employ hammers perhaps more than any other trade except tinsmiths. In addition to the varieties shown from A to M in Fig. 131, there are special kinds used in boiler and girder work, principally for riveting. Those from A to H, Fig. 132, are of various patterns suited to different situations, open or confined, J and K are for narrow places, such as close to angles, &c., the flat pane being useful here. L to O are scaling hammers, with chisel edges, for chipping the hard scale from boiler plates.

Mining and quarrying hammers are of plain forms, resembling the sledges, but having flat sides, relieved only by chamfering at the edges. Some are made with single or double-ended chisel faces for splitting and cutting. Bricklayers' hammers are very long, with a curved splitting end, and a square flat end.

Hammers for tinsmiths' and coppersmiths' use are numerous, on account of the nature of the trades. The planishing hammers, Fig. 133, A, B, and C, are for finishing operations; sometimes spring steel faces are attached to them, in order

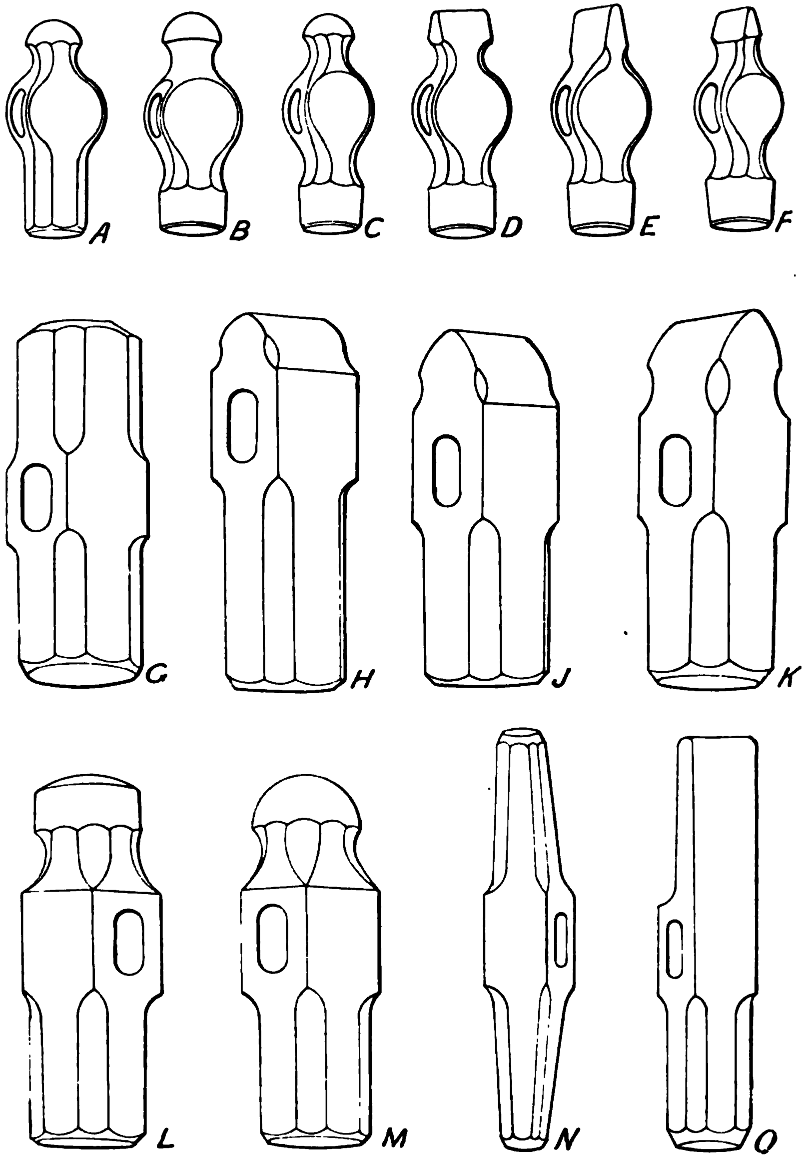


Fig. 131.—Engineers' Hammers.

to obtain smoother surfaces on the work. D is a hollowing or dishing hammer, E a cross pane, also made with one side circular in form. F is a bullet-head, used chiefly for riveting, G a paning hammer for closing up seams. A creasing hammer, H, is

used for producing grooves or creases. The hammer used for riveting is shown at J.

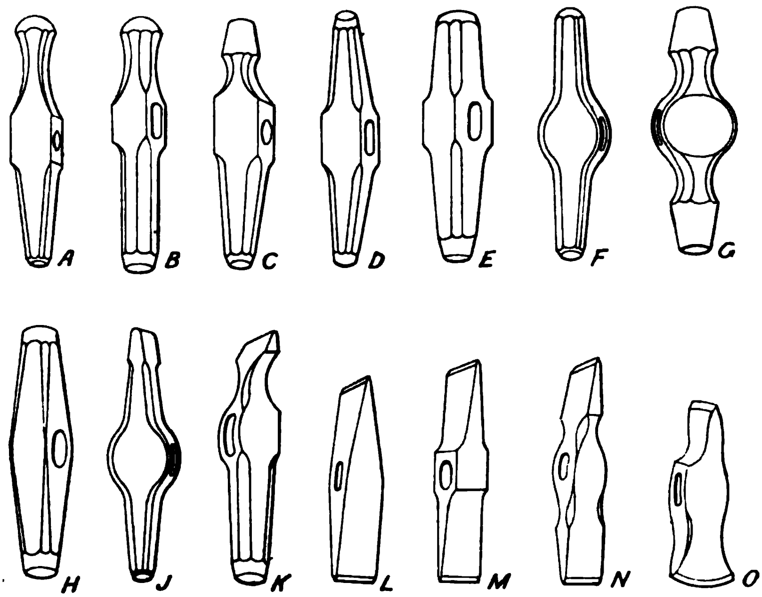


Fig. 132.—Boilermakers' Hammers.

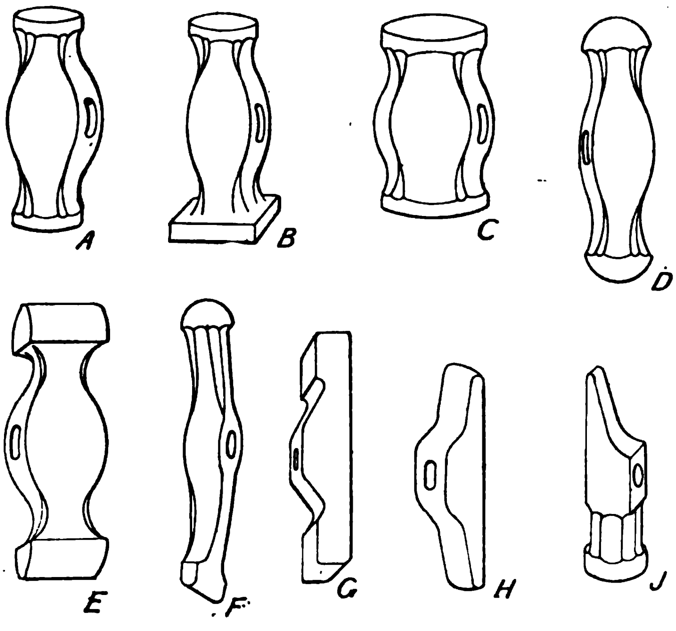


Fig. 133.—Coppersmiths', and Tinsmiths' Hammers.

Special hammers of lead, copper, babbitt metal, or raw hide are employed for finished work in fitting or machining, to avoid risk of damaging the surfaces. The soft metal is cast or otherwise held on the handle, being recast when too much out of shape to use. Raw hide hammers are made with hide held in a handle, renewal being effected when necessary.

All the steel hammers are held on their handles by wedge fastenings, the wedges swelling the split end out into the head hole, which is smaller at the centre than at the ends, so that shifting is impossible. The lengths of handles vary, ranging from 12 to 20 in. in hand hammers, and up to 40 in. for sledges.

Hammer Scale.—The scale which forms on the surface of forgings. Specifically the scale squeezed out from iron blooms under the steam hammer in the work of puddling. It is used as a lining for the bottoms of puddling furnaces, because, being rich in oxygen, it decarbonises the ore.

Hammer Shaft. — The handle of a sledge hammer.

Hand.—Prefixed to numerous terms, as hand brake—one operated by hand as distinguished from a foot brake or a power brake. A hand drill, which may denote a fiddle drill, or one actuated by a brace, or a ratchet brace, or a machine. Hand expansion gear relates to the adjustment of cut-off valves by right and left hand screws. Hand gear usually signifies the toothed gear of a crane, or other hoisting machine which is actuated by a winch handle. A hand hook is the hook form of wrench used by smiths. A hand lever is one provided with a suitable handle for grasping and operating it

PLATE VIII.

Fig. 136.—Hand Traveller, operated by Dependent Chains. (Thomas Smith & Sons.)

Fig. 138.—Hardening Shop of the Birmingham Small Arms Co.

To face page 146.

by. A hand pump may mean a common suction pump, or a force or test pump. A hand rest is the common tee rest of the wood-turner, and the metal-turner using hand tools. A handspike is a long wooden bar tapered at one end for turning hand capstans by. A hand tap, or hand working tap, is thus distinguished from a tap operated in a machine. Hand traverse, or traversing, applies to machine slides which are not self-acting. A hand vice is the small pin vice. A hand-wheel feed is one imparted to a feed screw by means of a hand-wheel. See also specific terms below.

Hand Crabs.—The general construction of light hand crabs is as follows:—There are two cheeks or side frames, either of cast iron well strengthened with fillets or ribs, or of steel plate, Fig. 134, A, A, which in the larger crabs is stiffened with an angle iron bent round, and riveted next the edge. In these frames, placed at a parallel distance apart with three screwed distance rods, are the bearings for the shafts. These are the barrel or drum shaft B, and the hand shaft C, in single purchase crabs, or barrel, hand, and intermediate shafts D in double purchase crabs. The barrel shaft also carries the large *barrel wheel* E, and the brake F for lowering by; the hand or winch shaft carries the pinion G and the winch handles, and when intermediate gear is present the winch shaft in that case carries a second or *intermediate pinion* J to gear with the *intermediate* wheel H, on shaft D. The height of the winch shaft should not be less than from 33 in. to 36 in. above the ground. The intermediate shaft when present is made to slide endwise in its bearings to throw either the first motion pinion into gear with the barrel wheel, or the second motion one into gear with the intermediate wheel; and has collars turned upon it, between which the pawl K drops to keep it in either gear securely. There is also a ratchet or dog wheel L on the drum shaft, or on one of the others, which prevents the load from running down if it happens to be necessary to leave it suspended temporarily.

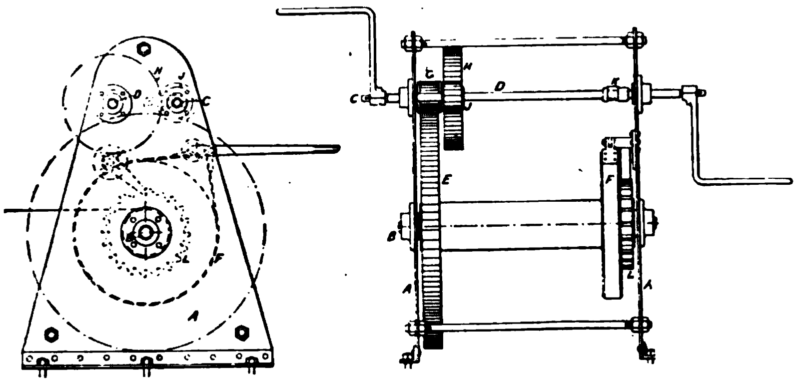


Fig. 134.—Hand Crab.

Hand Crane.—A class of crane which is only economical when the service is very intermittent. It is a survival from the first half of the nineteenth century when all cranes were operated by hand. The power available in these types is great, provided speed is sacrificed. Powers up to 20 tons have been common, and up to 40 tons occasionally. The application of hand labour is through winch handles, or often, in the case of overhead travelling cranes, of dependent ropes, or chains, and wheels. Single and double gears are usually combined, and treble gear for heavy loads, and sometimes also pulley blocks in addition for exceptionally heavy duty.

The group includes the triangular framed cranes of foundry pattern with racking carriage, the cranes with derricking jibs used on wharves, the wall cranes, the whip or warehouse cranes, and the derricks proper.

Hand Drill.—This may either be held and operated in the hands, or be of the larger bench, or pillar, or wall type, and driven by a handle or wheel. Excepting in the brace, gearing is

introduced in order to change the direction of motion to right angles, with or without speed increase or reduction. The portable types usually drive from a large bevel gear on the handle shaft to a smaller one or a pair on the drill spindle; or two sizes of bevels may be placed on the handle shaft to actuate either of a pair of companion gears on the spindle, at different speeds. The drills are gripped in a self-centring chuck.

Bench and pillar drills are also operated through bevel gears, the spindle sliding through its gear by splines to give the downward feed, which may be by hand, or self-acting. In the larger machines extra spur gears are introduced to give two or more changes in speed, with corresponding gain in power for the larger drills. A heavy flywheel is usually fitted, either on the handle shaft, or—where it is less in the way—on the top of the drill spindle. The capacities of hand drilling machines usually range up to $1\frac{1}{2}$ inch diameter; they are chiefly used in small shops where power is not available, or on out-of-door work, being necessarily slower in action than power drills.

Hand Drilling.—Generally signifies that done with a ratchet brace. It is not adopted more than is absolutely necessary, because the process is very slow, and then practically only in the erections of heavy work. The numerous portable machines, electrically driven, have to a great extent superseded the necessity for hand drilling.

Hand Feed.—Signifies in general a feed which is not self-acting. Specifically it is applied to wood-working machines, as saws, and planers, in which the timber is fed along by hand instead of by rollers, or drag ropes.

Hand File.—A synonym for flat file, but having less taper than the so-called flat files.

Hand Fitting. — Applied to the adjustments made at the fitter's bench as distinguished from work which is either not fitted at all, or black fits; and that which is assembled, or built as parts leave the machines. The present tendency is towards the displacement of hand fitting.

Hand Hammer.—*See* **Hammers.**

Hand Holes.—Small holes in boiler shells cut to permit of the insertion of the hands for the purpose of raking out deposits, and cleaning. They are similar to mud holes, and closed similarly, but are higher up than the mud holes proper.

Handing.—A shop term which relates to the case of patterns that have to be made right and left hand. A common example would be that of plated cheek castings ribbed on one side, and having bosses or bearings for shaft holes distributed at irregular centres. The pattern for these would not reverse, and therefore the ribs, and bosses or bearings are taken off one side after a mould has been made and screwed on the other. This device is, of course, only adopted for a pair of castings only, or when the number of pairs of castings required is not sufficient to pay for two patterns, made right and left handed.

Hand Ladle.—*See* **Casting Ladle.**

Handles.—The handle is nearly as important as its tool, as anyone knows who has endured the fatigue or soreness of using a tool with a handle improperly shaped.

The file handle must have a good ball end. If the end is pointed it will make the palm of the hand tender. A bradawl handle for the same reason must have a ball end. So must a screw driver, but this must also be broader in one direction than the other, and flattened, to afford leverage. A paring chisel handle used by thrusting vertically must have a bellied or globular form near the ferrule for the hand to grip and thrust. But chisels that are driven with the mallet chiefly, need be parallel only, or slightly bellied, or may have any fanciful shapes imparted. To these belong firmer chisels, mortise, and socket chisels. Turning chisels and gouges require little thrusting, but leverage has to be exercised, and ready manipulation. This is secured by handles considerably longer than those just named, about twice as long. The shape is of little importance, so that a good grip is secured. The handles of planes and saws must not be too thick, otherwise they tire the hand; a handle too thin would have the same effect.

The handles of hammers are elliptical in cross section to prevent them from turning about in the hand. They are of length proportioned to the nature of the blow delivered; from the comparatively short handle of the bench hammers

to the long ones of the sledges. Many are curved or cranked lengthwise to ensure a better grip against risk of sliding through the hands.

The handles of the fullers, flatters, setts, and other tools used by smiths and boilermakers are long, and loose to absorb the jars, due to hammer blows, and prevent them from tingling the hands. They are of iron rod, or of withy, bound round the necks of these tools. The setts often have rigid handles of wood, but as they are long the jar is absorbed, and the rigid handle is desirable to allow of the proper control of the sett.

The handles used on machine tools and mechanisms of various kinds differ widely according to their functions. The plainest form, that of a lever with a square hole at the end, is employed very extensively, its disadvantage being that of working loose in a short time. Where backlash is objectionable the handle must be either clamped or keyed on. The question of balancing is important in cases where vibration would tend to let the handle drop gradually, and so cause alteration; the lever may be either duplicated on each side of the centre, or the ball handle employed, having a globular extension of metal at the opposite end, to balance the weight of the knob, and the projecting handle which the operator grasps. This precaution is specially essential in machine tools, where the motion of a lop-sided handle may alter the position of slides, &c., and spoil work. Hand-wheels also provide a means of getting over this trouble and also serve conveniently to place graduations on their rims for micrometric setting. Handles are often made adjustable in throw, as for hand screwing and drilling machines, where the smaller tools may be operated more quickly with less throw of the handle. Means of locking handles in certain positions are provided when they are used for throwing in sets of clutches, gears, &c., a plain or a screw plug being used, fitting in sets of holes in a quadrant plate, or else a spring plunger device, which automatically locks the handle. The method adopted in reversing levers is also followed, by spring catches or ratchet faces. A notable development of recent years is that of fitting permanent handles to locking and clamping nuts on machines, to avoid the waste of time otherwise caused when a spanner has to be picked up each time the nut has to be tightened or slackened.

Hand Milling Machine.—Short and light pieces of work are often finished on milling machines, the slides of which are operated by hand levers, instead of with screw feed, or power feed. The levers partly rotate pinions gearing with racks in the slides, the movement being very rapid, and therefore suitable for repetition or "manufacturing" jobs.

Hand Rammer.—*See* **Moulders' Tools.**

Hand Ramming, Hard Ramming.—*See* **Ramming.**

Hand Riveting. — This has been to a large extent displaced by machine riveting. At one time there was much controversy as to the relative reliability of the two methods, but it is now generally acknowledged that the latter produces better results, besides great saving in labour costs. Long after machine riveting came into general use it was adopted only in plain work. Machines have been successively designed for operating in the most awkward situations. In hand riveting the services of two men and a boy are required—the holder-up, the riveter who closes the tails, and the rivet boy who heats them and supplies them as required. Small rivets used in thin sheets are hammered cold.

Hand Saw.—The saw which is intended primarily for cross-cutting boards, though it is often used indiscriminately both for cross-cutting and ripping with the grain. Its average length is 26 inches, with about six tooth points to the inch, the number sometimes varying, in order to have larger teeth towards the handle end, and smaller ones towards the point of the saw. A considerable amount of set is given to the teeth, and in filing them the file is tilted considerably to produce acute points on alternate sides, corresponding with the set. In saws used exclusively for ripping, the edges are filed more nearly, or quite, square across. The fronts of hand-saw teeth incline slightly back from the body of the saw to the tooth points, so that in its work the root of the tooth is in advance of the point. This inclination forms about a right angle with the back of the saw.

In the best saws the blade is not of uniform thickness throughout, but is thinner at the back to reduce friction in working, and thicker at the handle end than at the point, to give strength, with minimum weight. The *skew-back*, or back that is curved inwards instead of straight, is also designed to save friction and weight. The greatest improvement, however, has been in making blades thinner than those which were formerly employed. Lightness is not in itself a matter of importance, but a thick blade requires more exertion or more time to travel a given distance, owing to the wider kerf it has to cut to clear itself.

Hand Screw.—A form of cramp, Fig. 135, used by wood-workers for cramping glue joints together, and for holding anything temporarily

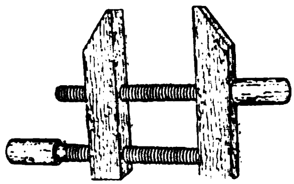


Fig. 135.—Hand Screw.

in position. The cramping pressure is not applied by parallel movement of the jaws and direct screw pressure as in other cramps, but after the cramp has been adjusted in position the back screw is used to spread the backs of the jaws and so by leverage close the fronts which grip the work, the middle portion being confined by the front screw. This gives a great deal of power, and also permits of a little adjustment to suit surfaces that are not perfectly parallel with each other.

Hand Shank Ladle.—A hand ladle. *See* **Casting Ladle.**

Hand Sketch.—A substitute for a drawing for use either in offices or shops. Ideas are outlined thus for the draughtsman to elaborate properly into drawings. Work is sketched for the shops, either to save the cost of a finished drawing, or to anticipate it, as when a breakdown occurs, or a rush order, some preparation of materials for which can be going on while the drawings are being made.

Sketches are sometimes made of portions of drawings, as when the bulk of the work on drawings has to be done in one department in which they have to be monopolised, and some small item only in another. Thus there may be a bit of plain smiths' work on a job consisting chiefly of patterns and castings, or a small bit of casting on a drawing containing forgings or plated work. A sketch is then made of that portion, and sent into the shop instead of the drawing. There are also foremen's sketches made from drawings, and given out to different men doing preparatory work, or sketches of new work, as shop appliances, out-door jobs, breakdowns, and so on.

In all hand sketches dimensions are necessary, but neat outlines are not. It is well not to have any very great departures from reasonable proportions. Substantially the only difference between a sketch and a drawing should be that between instrumental and hand-drawn lines. Similar views are required, and centres, centre lines, and rough shading of sections. Sometimes perspective views may be employed, if fully dimensioned. Squared paper is valuable for sketches, being helpful in fixing due proportions.

All hand sketches that come from the office are returned thither like the drawings, and put away, and located by numbers recorded in a suitable record, or sketch book, or by cards. Hand sketches fill a useful place in the smaller works, and they were used far more years ago before the sun-printing devices had been brought to their present stage of perfection.

Hand Tap. — A tap operated by a tap wrench instead of in a machine. The hand tap is much shorter than that used in a machine.

Hand Traveller.—A type of overhead travelling crane which, though to a large extent displaced by power operated cranes, is still indispensable in many small shops, and in situations where a crane is required only for occasional service. Though slow in operation, it costs nothing for service or power when lying idle. The traveller beams are built of timber, or of steel. Trussing is invariably used for timber, and for long spans when plain steel joists are employed, but built-up beams are made without trussing. The beams are attached to end cradles which run by flanged wheels on

gantries. The load may be lifted by a crab traversing the beams, or by a jenny, or racking carriage. The first-named carries all the hoisting gear, and gear for moving the crab across the beams, and also for travelling the crane along the gantries through a square or round shaft, though sometimes the latter movement is effected by winch handles and gears at the traveller end. In the second the jenny carries the hoisting drum and gears directly connected therewith. Or in many cases the gears are situated elsewhere, and the jenny is racked along, with the hook and snatch block only, and the guiding wheels for the chain or rope. Fig. 136, Plate VIII., illustrates a hand traveller operated by dependent chains from the ground, one for the travelling motion, and two others for the lifting, and the cross-traverse of the crab respectively. Fig. 137 shows in plan an alternative method of moving the beams of a hand traveller along. A rope wheel A actuates bevel gears, and the latter the longitudinal shaft which drives the spur gears on each of the running wheels at the end cradles, so avoiding risk of cross-working.

Hand Vice.—Much work that has to be filed, polished, &c., is too small to be held in the bench vice conveniently, and the hand vice is here found of service. It comprises two jaws, joined by a pivot at one end, and pulled together with a screw and wing nut, a spring located between the legs opening the jaws when the screw is slackened back. The disadvantage of the pivoting is that the jaws do not face parallel to each other, and this is obviated in other types of vices by making the jaws run on parallel ways, the opening varying in different sizes from $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. wide.

Hand-Wheel.—A valuable aid in effecting turning movements to screws and spindles, being an alternative to the use of a cranked lever. The advantage of the hand-wheel is that its rim can be felt in any position, while the crank handle has to be located. Hand-wheels have plain discs, or arms; the arms are in the plane of the rim, or are dished, the latter device throwing out the rim more conveniently for handling. Rims are properly turned smoothly.

Hang.—The way in which a hammer is held.

Hanger, Hangdown, or **Hanging Bearing.**—*See* **Bearings.**

Hanging.—Applied to the fixing of pulleys on their shafts. A grindstone is hung when it is adjusted or set truly. The term seems to have arisen from the old millwrights' work, when the necessary adjustment was by means of keys, the hole being larger by $\frac{1}{2}$ in. or more than the shaft, and more often square than round.

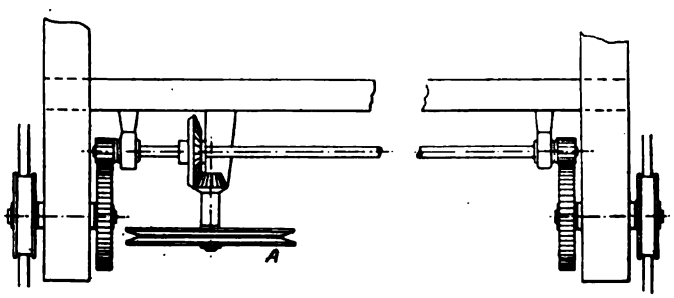


Fig. 137.—Gears for Actuating Hand Traveller.

Hanging Bridge, or **Inverted Bridge.**—A bridge occasionally placed in a furnace flue two or three feet behind the bridge proper. The space between the two forms a combustion chamber.

Harbour Making.—The machinery and plant and materials for this work will be found under numerous heads. *See* **Bag Work, Block Mould, Block-Setting Crane, Block Work, Concrete, Concrete Blocks, Concrete Mixers, Monolithic Work,** &c.

Hardening.—Signifies either the absolute hardening of the surface of an article to ensure its durability, or a stage towards tempering; the object being *let down* to the softer grade suitable for cutting tools, or for any degree of elasticity required. Hardening, or quenching is done mostly in liquid, either water, or oil; sometimes in mercury, occasionally in solids; as wax, pitch, or lead, or between metallic surfaces. The degree of heat and the methods of heating are as important as they also are in tempering.

A temperature indicated by some shade of red is adopted for hardening. But in modern

methods this is falling into disuse, because its estimation is not sufficiently accurate, and temperature is therefore regulated by thermometers in closed furnaces, when hardening is done in quantities.

The heating of steel preparatory to hardening must be done gradually. If done in the fire, the fire should not be too hot when the steel is inserted, but the temperature be increased gradually as that of the steel increases.

Difficulties arise in work of irregular shapes, having thick and thin portions adjacent. If the temperature is not uniform, warping will inevitably result due to different rates of expansion. Attention therefore should be given to the heating of thick portions. When work is of uniform dimensions the heating must be regular, and therefore slow, and the article turned about. The threads of taps, and teeth of milling cutters are frequently protected with soap.

Hardening is effected in cold water, preferably rain water, as it contains less lime than well water. Water which has been in long use is reputably better than fresh water. Water of icy coldness is best for hardening. Rock salt, or lime are often added.

Articles when being quenched, if of fair dimensions, should be moved about in the water to bring them into contact with fresh cool water, and remove them from the spheroidal globules produced by the heated work. The reason of this is illustrated by the necessity for pouring a stream of water over anvil faces, and the faces of large dies for smiths' forgings. Mercury, which does not volatilise, is for this reason an ideal hardening agent. Articles of considerable length must be plunged perpendicularly to prevent distortion, as well as be moved about vertically.

The more rapidly heat is abstracted, the better the hardening. This explains why objects must be moved about in the water, and why mercury is an effective agent, being a good conductor of heat. A large volume of liquid is necessary to prevent rise of temperature of the water during quenching.

By raising steel to the temperature for hardening, the iron carbide Fe_3C, or cement carbon, is dissolved in the iron. The effect of sudden cooling is to prevent the carbide from returning to its soft condition.

Successful hardening, therefore, depends, besides the percentage of carbon in the steel, on the temperature at which it has been cooled, and on the rapidity of the cooling. If too highly heated the steel will be brittle, if too low it will not be thoroughly hardened. Brinnel, experimenting on steel containing ·5 per cent. carbon, denoted the temperature at which the carbon passes from the cement to the hardening state by the letter W, and that at which it passed from the hardening to the cement form as V, this being suitable for the annealing of steel. If the temperature W is exceeded previous to quenching, the steel becomes more crystalline and brittle; if it is not reached, the steel is not fully hardened. Mr Brayshaw has stated that a difference of 5° Cent. is sufficient to make the difference between good and bad hardening. Some experiments made with a view to determine the best temperatures for hardening proved that the variation between moderate and maximum hardness occurs between 977° Cent. and 1078° Cent., a range say of 100°. A bar of fine Jessop steel was taken and notched at distances of about 60 mm., and each section numbered, and heated in a lead bath, hardened, broken off, and tested. No injury was suffered at 1078° Cent., but over that temperature deterioration set in, while below 977° Cent. the hardening was imperfect.

Though rapid cooling is essential to hardening, yet when there is considerable mass the cooling must be delayed, otherwise cracks will form, due to the exterior hardening and shrinking before the interior. This makes the hardening of large drills and milling cutters so difficult. The subsequent letting down for temper helps to release the internal stresses set up.

Hardening in air is adopted in some cases, the object being waved about in a current of air, either natural, or blast. It is said that Damascus blades were tempered in this way in winter time, when a cold strong north wind was utilised. This air was allowed to come through a slit in the forge wall on the red-hot blade held in front of the slit. The high-speed tool steels are hardened in air, being either laid

down at the side of the forge, or having a blast directed on them.

Thin articles to be hardened must have the scale removed by grinding, otherwise the heating will not be uniform.

The difficulties and uncertainties of hardening are due largely to the variations in the qualities of different steels. Hence different temperatures are necessary for heating and quenching the various brands. And as shades of colours vary with temperatures, the precise estimations of these become difficult. As overheating is always to be avoided, it becomes necessary to lay down the rule, that the *lowest* heat which is suitable should be ascertained in all cases. *See also* **Annealing, Armour Plate, Case Hardening, Tempering,** &c.

Hardening Compounds.—Physics added to water when steel is deficient in carbon, or to expedite the cooling action of the water. They include common salt, rock salt, alum, sal-ammoniac, corrosive sublimate, ammonia, parings of hoofs, yellow prussiate of potash, borax.

Recipes for making steel very hard are the following:—8 oz. of powdered prussiate of potash, 8 oz. of powdered borax, 6 oz. of salt dissolved in 8 gallons of water. Or, one half teaspoonful of wheat flour, one teaspoonful of salt to two teaspoonfuls of water, made into a paste to cover the steel to be hardened, which requires to be warmed for the purpose. Then heat to cherry red, and quench in cold water. Another is, 2 oz. of saltpetre, 2 oz. of sal-ammoniac, 2 oz. of crushed alum, 1½ lb. of salt, to 3 gallons of soft water. Another, 1 oz. of corrosive sublimate, 8 oz. of salt, 6 quarts of soft water.

Hardening Furnaces.—The development of the cycle industries and of other special industries on the interchangeable system of manufacture has been favourable to the growth of special furnaces for heating articles uniformly for hardening purposes. Gas is the fuel used, the temperature is regulated, and also the time required for heating. A few descriptions of typical furnaces are here given.

In a machine by the American Gas Furnace Co. for balls for bearings, and similar objects, a cylindrical body, with its axis horizontal and lined with fire-brick, contains a cast-iron cylinder within which a continuous spiral is formed. Its shaft is a wrought-iron pipe carrying a spiral, all revolving together, driven by worm gear. There is a hopper at one end in which the work is placed. A scoop revolving with the cylinder picks up portions and drops them into a feeding funnel, by which they are discharged into the inner spiral, the revolution of which feeds them along to the farther end, whence they drop into the spiral way in the outer cylinder, and so work back towards the hopper end, and drop from the cylinder into the hardening bath.

Supply valves for gas and air permit of the regulation of the temperature of the drum, and a friction cone on the countershaft, driving to pulleys on the worm shaft, allows the time required for heating and delivery to be regulated with precision. Preliminary heating is required to raise the temperature of the spiral ways. The articles need not be of the same dimensions. If the temperature is regulated to suit the heaviest articles, the thinnest will not be overheated. The machine is suitable for hardening cycle balls, nuts, screws, bolts, &c., at the rate of from 1,500 to 2,000 lb. per day.

As quenching the work raises the temperature of the oil used, the output cannot exceed the capacity of the bath, which should be large. The bath has therefore to be maintained cool by water jacketing, the water being circulated at a rate to keep the bath at a proper temperature, as regulated by a thermometer. Or the oil is run off from the top, passed through pipes immersed in cold water, and pumped back cool to the bottom of the tank. Or if the water is not sufficiently cool, ice may have to be used.

In another design by the same firm, a link belt is used for conveying the articles to be hardened through the furnace. The latter encloses the belt, excepting for an opening through which the articles are dropped on the belt. The same methods of regulating temperature and speed are employed as in the previous example. In another an endless chain carries pins standing up vertically, while the chain is moving through the heating furnace, and which, on leaving, throw off the articles stuck on them

into the cooling bath; the sag of the chain lying below the furnace, which is carried on legs. This is used for pinions, cones, shells, and other articles provided with holes. In another design the articles are carried in trays that are rotated two or three times in a minute in the furnace, being suspended from rods connected by spokes to a central driving shaft, operated by worm gear.

Fig. 138, Plate VIII., illustrates the gas hardening shop of the Birmingham Small Arms Company, from which it will be seen that the centre of the shop is occupied with benches, provided with a few vices, and rows of furnaces run down against the walls, the chimneys leading into a common horizontal flue.

Hardenite.—Martensite which contains the maximum amount of carbon. The term martensite is given to the microscopic appearance of steel that has been quenched suddenly from a high temperature. Under the microscope it appears like a system of interlacing crystalline fibres.

Hard Metal.—The moulder is ever between two fires. The machinist requires soft metal —stuff that can be easily tooled, the purchaser wants something tough, hard, durable. These perennial troubles haunt the foreman moulder who, mix his metal how he may, finds it impossible to please everyone.

A turner or planer is complacent when he sees the chips falling down in great chunks "like cutting cheese," and the graphite dust much in evidence. But this is not the proper metal for wearing parts, though it is suitable enough for frames and solid masses that simply afford support to mechanism, or form connections. This is well understood in making engine cylinders, and liners, slide bars, crosshead guides, &c., in regard to which specifications are generally strict. Such castings cost more for tooling, but the friction of their parts is so excessive that it is necessary to insist on close-grained metal, moderately hard, and slippery. But there are thousands of other details which are subject to just as much wear, and which should properly be of cylinder metal, or a mixture running very close to it. The following may be instanced out of many. The reversing cone clutches, such as used on cranes. These must always be run metal to metal without lubricant. Under hard service these, if of soft metal, will wear themselves out in a few months. Worm gears, and spiral gears, the friction on which is excessive. Spiral gears under hard duty will wear out in a few months. If expense is no consideration, phosphor bronze is better than iron, or phosphor bronze may run with iron or with steel. The same remark applies to worm gears, but the trouble with these is got over by running them in oil. Nevertheless the metal should be hard. The slides and strips of machine tools. The temptation to use soft metal is great, because the surfaces to be tooled are large, and because soft metal is less liable to produce curving and distortion, and uncertain shrinkage in cooling. This is a case in which a mean must be struck. Toothed wheels should be made of close-grained metal. They soon wear if soft, especially high-speeded wheels.

The limit to the use of hard tough metal is when it becomes so highly contractile that unsafe shrinkage strains are set up. These produce internal stresses, and sometimes "draws" in vital sections. But a metal must be very highly mottled—very close to white before this occurs. These evils are seen at their worst in steel castings, the excessive shrinkage of which occasioned much trouble in the early days of steel making. Many steel castings have to be stiffened up with brackets, and very large radii in weak sections, solely with the view of affording sufficient strength to prevent the shrinkage strains from causing fracture at those sections.

A foundry man who is experienced in mixing is able to obtain metal of any grade by observing the fracture of the ingredients before they are put into the cupola. To a large extent he is helped by using proportions of pig of known brands, but in regard to scrap the appearance of a fractured surface is a sound guide. Grey open pig, and scrap iron yield soft open castings. In the mottled irons, and their judicious proportioning lies the principal secret of getting castings of varying degrees of mottle, toughness, and hardness. Good coke, of course, is essential, and thorough melting. In time the laboratory will largely supersede this kind of experience,

which, however, is not rule of thumb, as technical men choose to call it.

The mere hardness of metal taken alone is less objectionable now than formerly, because

culty of tooling it. For this reason, therefore, we should trouble less about the desire of the machinist for soft iron, and consult more the customer who wants durability.

Hard Solders.—Solders composed mainly of copper and tin in an extensive gradation, with a range of fusing points suitable for uniting copper, and alloys of the same. The strongest hard solder for copper goods is, 3 copper, 1 zinc.

brass, 1 copper, 1 zinc is suitable.

Hard Water.—*See* **Carbonate of Lime, Boiler Scale, Clarke's Process, Feed Water.**

Hardwood.—A general term used to dis-

tinguish one great group of woods from another. The varieties of hardwood are much more numerous than those of softwood. The latter belong only to the needle-leaved, coniferous, or cone-bearing, resinous trees. All others are known as hardwood. Their leaves are generally broad. The pores in the end grain of the wood can be distinguished easily. The grain is closer and the wood generally

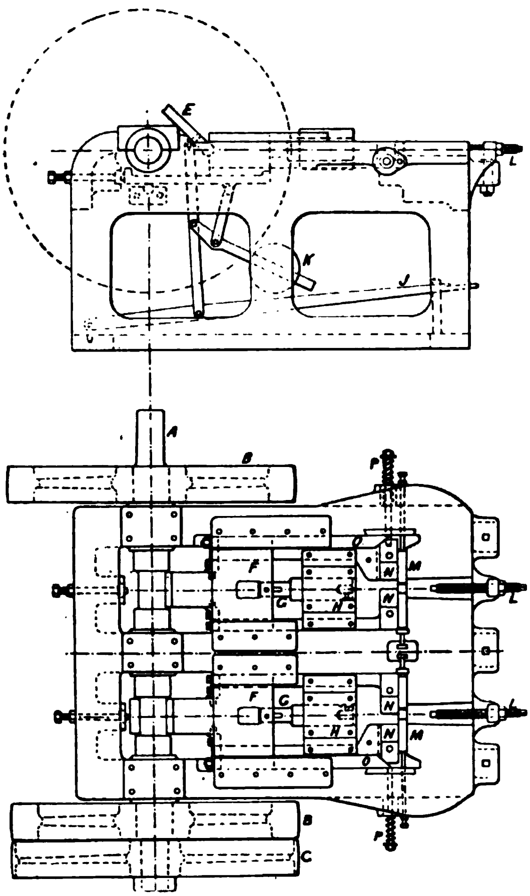


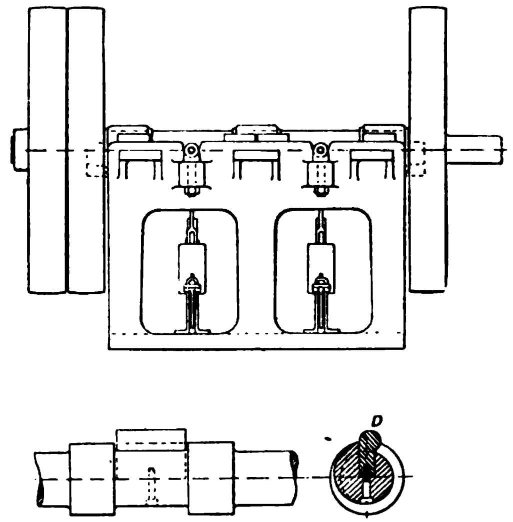
Fig. 140.—Heading Machine.

harder and heavier than that of the softwood class of trees. The leading varieties of hardwood are oak, mahogany, ash, elm, &c.

Hatchet Stake.—*See* **Stakes.**

Hat Leather.—*See* **Hydraulic Leathers.**

Haulage Gears.—Used for endless rope, and main and tail systems in mines, quarries, collieries, and in open country where steep hills and uneven ground prevent the utilisation of narrow gauge railways. The ropes are wound on drums or pulleys, and put into and out of action by clutches. They are driven by gears to gain power; or directly, and have powerful brakes. The drums are of cast iron wholly; or cast-iron flanges, and ends have a body of steel plate riveted between, or the body is formed of wood lagging. There are numerous designs. The



one shown in Fig. 139 is motor-driven, and is engaged by one of Heywood & Bridges' friction clutches. Rolled joists form the bedplate, to which the shaft bearings are bolted. The motor A drives through the double gears seen to the drum B, through the medium of the expanding clutch C, which opens out and makes frictional contact with the interior of the brake ring at the end of the drum. The hand-wheel D through the screw and levers shown operates the clutch. The powerful strap brake E is actuated by the foot lever F through the rods and levers which may be traced out. The controller, of tramway type, will be noticed adjacent to the motor. In what is termed the double-endless haulage gear, two pulleys, each with its separate brake are used. Rope of any length can be employed then, a single bight being passed over the pulleys. In other respects the construction is similar to that in Fig. 139.

Hauser Rope.—A cable laid rope in which three common ropes are twisted from left to

right, being in a direction the reverse of the twisting of the strands in the several ropes.

Hawse Pipe.—A casting through which a chain passes. It is slightly bell-mouthed, or convex-edged.

Hay Bands, or Hay Ropes.—Hay twisted into bands, and used as a supporting body for laying loam on in sweeping up loam cores and patterns. It forms a porous self-venting mass, through which the gases escape into the core bar. The bands are spun on a revolving cross, or in a special machine, in any length required, and from 1 in. to $1\frac{1}{2}$ in. diameter.

Hay Band Spinner.—A lantern wheel on which hay ropes are formed, the hay being fed on it as it rotates; the hay is thus twisted into form.

Hay Stack Boiler.—A **Balloon Boiler.**

Hazel (*Corylus Avellana*).—Used on account of its elasticity and toughness for the handles of smiths' tools; fullers, flatters, and swages.

Head.—The weight of a column of liquid due to a given height; or the height, as 50 ft. of head. The weight or pressure is equal to the height multiplied by the specific gravity of the liquid. The potential energy of head is the product of height, into weight, per second. The vertical head of water in feet multiplied by ·434 gives pressure in lb. per square inch. Losses of head due to friction have to be taken account of, and minimised in various ways. The term head denotes the opposite of foot, or tail, as the head of a screw, or nail, or bolt, or hammer, or rail, &c. Head is a prefix to many terms, some of which are given below. It is also used as an affix, as cross-head, drum-head, live-head.

Headers.—Denotes the radial setting of bricks. This is the arrangement in cupola furnaces. In brick tanks for gas holders, headers alternate with course laying, about every fourth layer being headers. Thus the work is bound together more effectually. Also chambers which receive the ends of the tubes in water-tube boilers.

Heading Machine.—A type of power-driven press employed for upsetting plain bars to produce bolts, spikes, rivets, &c., at a single blow. It is an alternative to the vertical forging press illustrated under **Bolt Making,** but unlike the latter will head bars of any desired length.

The views (Fig. 140) give elevation, plan, and end elevation of a machine by Taylor & Challen, Ltd., taking bars up to 1 in. diameter. The driving shaft A runs at thirty-five revolutions a minute, rotated by one of the belt flywheels B B, the belt being thrown off to the light loose

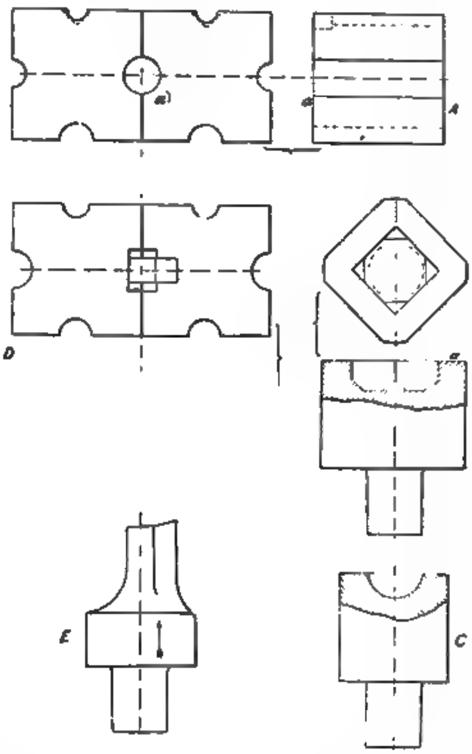


Fig. 141.—Grippers and Dies for Heading Machine.

pulley C when desired. This pulley may be placed to run on either side of the machine, as convenient, the shaft A being prolonged at each end. Shoulders are formed at two places, mid-way between the frame bearings, the spaces being turned in cam fashion as shown in the enlarged detail, and knuckle pieces D fitted in slots and held with sunk screws. Plates E E are pivoted on trunnions in slides F F, running in guides in the frame and cottered loosely to the die holders or rams G G, sliding in bearings H H. The plates E are brought into engagement with the knuckles D by the depression of the treadles J J, which through the connecting

levers seen in the elevation draw E E down, so that the knuckles catch them, with the result of driving forward the slides F and giving a blow to the rams G. The treadle gear is counterbalanced with the weights K K, to bring the treadle up again, and a slide and roller device is fitted (seen in the elevation) to enable the levers to follow the slides E to and fro.

The bars to be headed are heated and dropped in the spaces in front of the stop screws L L, being guided centrally by recessed plates M M. Half-dies or grippers are attached to the portions N N, the outer ones being made to move inwards by the action of wedge-ended strips O O, driven along by the slides F, and subsequently outwards by the action of spring plungers P P. When, therefore, a bar is placed in position, it is gripped immediately before the dies reach it, and thus held against the pressure of the forming action. On the return of the die ram the grippers release the bolt. Examples of grippers and dies are seen in Fig. 141, A being a pair of grippers, lying in contact, and made to take four different diameters of bars, the recesses on the top side including provision for making square necks. B is a die for a chamfered square head; it will be obvious that the face *a* in B makes contact with *a* in A when the pressing of the head is complete. A rivet die is shown at C, a similar class of gripper to A being employed with it. A gripper and die which includes the making of dog-spikes are given at D and E, the formation of the gripper recesses and the die end being clear; the dotted line in the section D shows the position of the end of the spike. Heading is also done in **Cartridge-Case Making.**

Heading Tools.—Tools used by smiths for upsetting the heads of bolts by hand. The stems pass through a hole in the tool, and the head is hammered out upon the face. The bolt is finished with a die, or in hexagonal swages. In bolt machines the work is done at a single squeeze.

Head Metal, or **Dead Head,** or **Sullage Head.**—A supplementary portion on top of a casting, the object of which is to receive the lighter matters from the casting below, as oxide, dirt, and entangled gases. It is adopted principally in cylinder castings for engines and hydraulic work, in which soundness and clean bores are required. It is also employed in steel ingots. The depth of head metal is variable, being increased in proportion to the degree of soundness required. It may range from about one-fourth the depth of the casting to as much as one-half. Its thickness should be at least equal to that of the body of the metal in the cylinder, and radii should connect the two in order to facilitate the free movement of the lighter matters upwards.

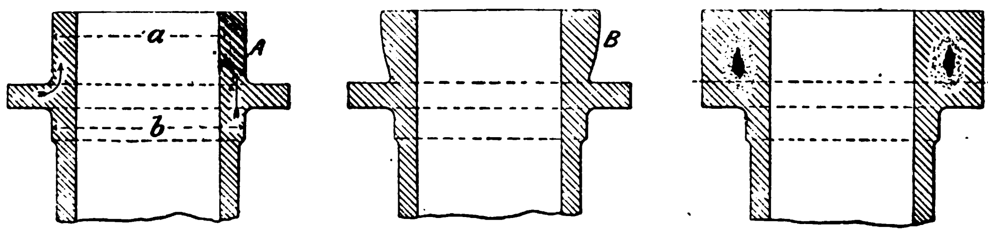


Fig. 142.—Head Metal.

In Fig. 142, A, the diameter *a* is the same as that of the cylinder belt at *b*. The sullage therefore has a free course upwards. There is also a radius connecting the head to the cylinder flange. This likewise facilitates the ascent of the dirt as indicated by the arrow to the left. B shows a device that is sometimes adopted, the head being enlarged above to give a greater space for the dirt to accumulate in. The plan shown on C is not a good one because the mass of metal is liable to produce draws, as indicated in the figure, with the result that the face of the flange is likely to be spongy.

Head of Water.—*See* **Hydraulics.**

Headstock.—The opposite of tailstock. It signifies primarily the head which carries the running mandrel in a turning lathe, hence the term *live* head as opposed to the *dead* head in which the mandrel does not rotate. It is also

termed the *fast* head, because it is fixed on the bed, while the other head is the *movable* head. Occasionally it is termed the *fixed*, or the *front poppet* in opposition to the poppet proper, or *movable* poppet or *back* poppet. Unless otherwise stated, the headstock is always understood to have a running mandrel. If the mandrel is fixed, so that the work rotates between it and the poppet, the term *dead centres* is applied, and this is generally fitted to cylindrical grinding machines.

The designs of lathe headstocks are varied so much that at extremes they have no points in common beside the mere running mandrel in a fixed head. In mass, in the details of mandrel fittings, in back gear arrangements, in connections to other parts of the lathe, as feed rods, and lead screws, variations are almost innumerable. The all-gear heads of the new lathes developed by tools of high-speed steel are a remarkable innovation. The headstocks of turret lathes and automatics are a group by themselves, differing in almost every detail from those of standard lathes. The headstocks of grinding machines afford examples of types distinct from either of the foregoing. Under these circumstances we must indicate some of the leading conditions that govern the design of headstocks in general, leaving the details of various kinds to be observed in the illustrations of various machine tools in this work.

The conditions which have to be fulfilled in a lathe headstock are ample rigidity, far exceeding that corresponding with mere strength; a truly running spindle with the best possible provision for taking up slight amounts of wear; a definite range of driving speeds; provision for attaching chucks, to ensure security and true running; means in most cases for gaining power by back gears; suitable means of connection between the headstock and the slide rest.

Rigidity.—The older gaunt design of a base and two uprights connected with small radii has developed into the modern style, in which bold curves sweep round, hugging the speed cones as closely as possible, approximately following a parabolic curve. As in large machine framings, large headstocks are hollow, so that rigidity and massiveness are ensured with a moderate amount of metal. In this way the risks of chatter in heavy cutting are eliminated.

Mandrels, or *Spindles.*—The constant tendency has been to increase the dimensions of spindles in order to secure rigidity and bearing area in the journals. The shape of the mandrel is not that which mathematical deductions would give. In theory it would be of double parabolic outline, the bases meeting in the front bearing, and the stresses and dimensions would be nil at the nose and at the tail. Actually most mandrels are of smaller dimensions at the hinder than at the front end; and the front bearing is always larger, generally much larger than the hinder one. The practice of making mandrels hollow has had much influence in increasing their dimensions, because the tendency has been to make the holes of increasingly large capacity for bars.

Dimensions are more easily settled than the methods for taking up wear. The standard English style with coned necks of hardened steel, running in bushed bearings of hardened steel, is not adopted so much as formerly. There is no better, or more durable, or more all-round satisfactory fitting than this, when well made. There is nothing worse, with bad workmanship, and soft surfaces. The risks are those of seizing and scoring. The growing practice is to employ parallel bearings of hard copper alloy; wear is sometimes then taken up endwise, but more often circularly, the bearings being split and closed with ring nuts. When parallel, the external portion is coned to draw along in a coned seating in the headstock by the turning of the nuts, so closing the splits. The screws are generally square threaded. Similar devices are generally adopted at back and front bearings.

In the more massive lathes the bearings are simply divided with caps, the wear being almost inappreciable. The bearings are frequently of cast iron, which wears excellently with large areas, and at slow speeds.

There are several ways of taking the end thrust of a mandrel which comes on when facing. The pointed tail centre is suitable for light lathes. Heavy ones have a flat surface bearing against a flat tail pin. This, however, is falling into disuse, its place being

taken by ball friction, following the friction washer device. The tail pin of many recent lathes cannot be used with hollow spindles. A good many lathes have protecting dust caps in combination with the nut used for taking up wear.

Speeding.—The stepped cones have afforded the only means for changing speeds until the recently developed electric drive has given rise to a new head—*the all-geared* (*see* **High-Speed Lathes**) in which the speed cones are absent. The cones range from three to five, or six in number. They run loosely on the mandrel, in order to permit of their driving the spindle direct, or through **Back Gears**. The necessity for belt shifting is an objection to the cones, and the fact that there is no regular gradation of speeds, but steps only, is unfavourable to the most economical turning and facing.

As the power of belt driving increases in proportion to width, and as a large arc of contact is also essential, we find that the modern stepped cones are much wider and larger in diameter than those of a few years since. At extremes these proportions have been more than doubled. One result is that much turning is done at a high speed by belt driving alone, instead of at a relatively slow speed with back gears thrown in.

Attachment of Chucks.—The common lathe chucks are well fitted with a screw to the mandrel nose. This screw is coarsely threaded to delay wear. The chucks for the capstan lathes and automatic screw machines are fitted in various ways; with quills or bushings inside the nose of the hollow mandrel. In some heavy lathes the chucks are permanent fittings, as in face lathes, boring mills, &c.

Connection with Slide Rest.—Here, though the work lies mostly outside the headstock proper, yet the method of connection modifies the headstock design. Two principal connections are made in a complete lathe, one for turning, another for screw cutting. In the older design of lathe, the first is made to a key-grooved or splined shaft at the rear of the bed—the back shaft. In the American type, and others modelled after it, the shaft is placed at the front, below the lead screw. Though these are generally kept distinct, yet in some few cases they are combined by splining the lead screw to enable it to serve for feeding. This practice is not commendable, and has not developed in any great degree. When the two are kept distinct they are in some designs operated by the same set of change gear wheels in a definite ratio as, say, 5 to 1, by which the mechanism is somewhat simplified. More often they have their distinct sets of operating mechanism, in which the turning feeds are much fewer than the possible combinations of change gears. The feeds are either by belt or gears.

The high-speed steels are radically altering the conditions of headstock design. The speed changes effected with steps of small diameter, and in a very limited range, yet with a considerable difference in each step, no longer fulfil the requirements demanded. They have answered fairly well with the ordinary tool steels, but fail entirely to utilise the new tools. It is a thorough reversal of the old condition. The lathes were formerly ahead of the tools, now the tools dominate the lathe. *See* **High-Speed Lathes**.

Mr P. V. Vernon has tabulated the conditions which should govern the speeding of headstocks and similar driving heads of other machine tools, involving stepped cones, and back gears. They are as follows:—

(1.) The total range of speeds should be sufficient for all reasonable requirements. (2.) The speeds should be sufficient in number. (3.) The speed changes should be in geometrical progression through the whole range. (4.) The smallest step in the cone pulley (where used) should be as large as possible, so as to obtain an efficient belt drive under all conditions. (5.) The drop from one step of the cone pulley should not be great enough to render it difficult to move the belt. (6.) The gear ratio should be as high as can conveniently be arranged, so as to obtain a relatively high belt speed when on heavy work.

Mr Vernon has proposed to estimate the "power value" of a headstock by the square inches of belt passing over a pulley in a minute, divided by the linear inches of cut per minute. This is based on the approximate rule to allow

1 HP. for every 10,000 square inches of belt passing over the pulley per minute, the effective belt tension being taken as 39·6 lb. per inch of belt width. It is necessary to take the cutting speed into account; and then the sectional area of the cut, which can be taken on any speed and diameter, will vary with the power value, irrespective of the design of headstock. The actual power of the headstock at a given diameter and speed is represented by the power value. The results can be plotted in a curve for a series of diameters at a given cutting speed, in which the ordinates or horizontal lines represent the power values, and the abscissæ or verticals, diameters of work. A complete chart of this kind for a given headstock is useful. A point which the chart brings out is that the power is always in excess in turning small diameters, and the construction and examination of a chart is recommended because it would show by the minimum power values when a lathe is deficient in power.

Mr Hetherington measures the power of a headstock thus:—Multiply the diameter of the large step of the cone by the width of the belt, and by the total gears. The result he terms the "units of belt and gear effort." It is the maximum power of the headstock, irrespective of the speed of cut, and is useful as a measure of comparison of headstocks.

Thus take case A: Large diameter cone, say 17 in., belt, say $3\frac{1}{2}$, say double gear 12 to 1, thus—

$$17 \times 3{\cdot}5 \times 12 = 714 \text{ units.}$$

Case B: Cone 21 in., belt 4·25, double gear 16 to 1—

$$21 \times 4{\cdot}25 \times 16 = 1{,}428 \text{ units.}$$

Showing that B is 100 per cent. more powerful than A, both say 12-in. lathes.

Headstocks for Grinders.—The demands of precision grinding have developed a headstock which embodies the most perfect practical provisions for accurate running, for taking up of wear, and for protection from injury. The spindle bearing is either continuous, or if divided as it often is, in order to place the driving pulley between bearings, yet all the available length is occupied by bearing area; the spindle is hardened and ground, and the bearing, usually of phosphor bronze, or hard gunmetal, and parallel, also ground. This is split, and covered with a cap bolted down on it, fine screws affording means of adjustment for wear. Two pulleys are fitted, one towards the rear, but some distance away from the end of the spindle to afford a nearly central pull of the belt. This is for running the spindle, the other on the nose is for dead centre work only, the spindle not rotating. Dust caps are fitted in various forms. Chucks are fitted to the spindle nose by screwing.

Heart and Square Trowel. — *See* **Moulders' Tools.**

Heartwood.—A matured tree trunk consists almost entirely of heartwood, an inch or so of the outer surface only being sapwood. In an immature tree there is more sapwood than heartwood. The heartwood is the only portion of the trunk that is of any value to the wood-worker. It is harder, denser, and much more durable than sapwood. The ordinary timber trees are called *exogens*, because they increase in diameter by outward additions. The outer portions of their trunks are always sapwood, and between this and the fully matured heartwood there is a less matured portion. When a tree is matured before being cut, there is very little waste due to the exterior sapwood. The latter in most trees is light, soft, and spongy, and easily distinguishable from the heartwood.

Heat.—The great and important subject of heat touches engineering at many points. Heat is a result of chemical action in the combustion of fuel in the furnace; it is produced by mechanical action in bearings, and wherever friction, pressure, percussion, or cleavage takes place; by the passage of an electric current through a wire; conduction of heat takes place through boiler plates, and radiations from boiler surfaces and boiler seatings. The rapid generation of steam is connected with the question of convection, and so on.

The terms heat and temperature must not be confused. The latter is merely a state. The total quantity of heat in a bucket of tepid water may be greater than that in a red-hot soldering iron, but the temperature of the latter is higher than that of the water. Thus heat and temperature may be likened to the

question of *level* in liquids. The total quantities of liquid in two reservoirs are immaterial, but if one has a higher level than the other, the liquid tends to flow from the higher to the lower level; and just as at a landing stage, for example, the levels of low and high tide may be marked, and the intervening space equally divided, so two extreme points of temperature may be selected, equal intermediate divisions marked off, and a scale drawn up. *See* **Thermometer**.

The general effect of heat upon solids, liquids, and gases, is to produce expansion. In the case of solids an undesirable proof of this is seen in bearings—when overheated axles stick fast. This effect of heat is also either utilised or avoided in shrinking on tires; in the compensation balance, or gridiron pendulum of watches and clocks; in riveting; in the construction of iron bridges; in the fitting of water pipes with telescopic joints; and the heating of iron rods before fastening the exterior plates for straightening bulging walls.

Conversely, the abstraction of heat from a body produces contraction, but a remarkable exception to this is seen in the case of water. As heat is lost, water increases in density, and where the loss is due to radiation as in rivers, lakes, &c., the surface water sinks to the bottom. But at 4° the water ceases to increase in density, and as the loss of heat continues, actually expands by about $\frac{1}{10}$ of its volume. While this interesting exception to a general law is highly beneficial to sub-aqueous life, it is woefully disastrous to the water pipes in factories and other buildings. As the water expands into ice, the pipe bursts, and the damage is revealed when a thaw sets in.

Again, with equal increments of temperature the rate of expansion of different solids or of different liquids is not uniform. For an increase of one degree, cast iron expands 1 part in 162,000; copper, 1 part in 104,400; lead, 1 part in 63,180; and zinc, 1 part in 61,920. Similarly, expansibility varies even among different kinds of the same metal or alloy, as iron and steel. So, too, with different liquids—alcohol expands more than water, and water more than mercury. All gases, however, expand regularly with equal increments of temperature, and the rate of expansion has been found to be $\frac{1}{273}$ of their volume at 0° C. for each increase in temperature of 1°.

Heat may be communicated from one body to another in any of three ways—(*a*) convection; (*b*) conduction; (*c*) radiation. Convection differs from conduction in that the heated molecules themselves carry the heat from one part to another, while in conduction heat is passed on from one molecule to another. Conduction is illustrated in the heating of the handle of a poker one end of which is in the fire; convection in the gradual heating of the whole mass of water in a boiler or kettle. The movement can actually be seen in a beaker of water placed over a flame, if small pieces of bran or similar light substance be thrown in the water. The currents formed are called "convection currents." The Gulf Stream is a gigantic example of a convection current. The metals are all good conductors of heat, copper and silver in particular possessing this quality in a high degree. Slight impurities, however, considerably affect the conductivity of copper. Liquids and gases are bad conductors of heat. The miner's safety lamp depends for its action on the high thermal conductivity of the wire gauze surrounding the flame. Free gas in the mine may pass through the gauze, and burn around the flame, but the heat of the flame is conducted away so rapidly by the gauze that no combustion can take place outside the lamp. The standard by which the thermal conductivity of a substance is measured, is the number of thermal units conducted through a unit of area of that substance of unit thickness in a unit of time, the two sides differing in temperature by one degree.

Heat is transmitted by vibrations of the ether in the same way as light, and the laws of the transmission of radiant heat are identical with those governing the transmission of light. In both cases, (*a*) waves are propagated in straight lines and in all directions round a body; (*b*) the laws of refraction and reflection are alike; (*c*) intensity varies inversely as the square of the distance of the source. Radiant heat and light are in fact identical. And just as some bodies transmit light freely and others not at all, so some bodies offer no opposition to

the transmission of radiant heat, while others arrest its passage. These qualities, which in the case of light are termed *transparency* and *opacity*, are called *diathermancy* and *athermancy* when speaking of radiant heat. It does not necessarily follow, however, that bodies which allow or arrest the transmission of light, act similarly in respect of radiant heat.

In the earlier part of this article it was stated that differences in temperature were akin to differences in level of two liquids, and that the thermometer revealed nothing as to the total amount of heat in a body. The measurement of the total quantity of heat which a body receives or parts with belongs to that branch of the science called calorimetry. The unit of heat is the amount of heat required to raise the temperature of 1 gramme of water to 1° C. This is called the thermal unit, or calorie. Another calorie is used in the measurement of large quantities of heat—the heat required to raise 1 kilogramme of water 1° C. The British Thermal Unit (abbreviated B.Th.U.) is the amount of heat required to raise 1 lb. of water through 1° Fahr. The large calorie just mentioned is equal to 3·97 B.Th.U.

The specific heat of a substance is the ratio of the amount of heat necessary to raise a unit mass of that substance 1°, to the amount of heat necessary to raise an equal mass of water 1°; or, more briefly, the number of units of heat required to raise a unit mass of the substance through 1° C. The specific heat of water is taken as unity, because it has a higher specific heat than any other substance. The following are the specific heats of some of the more important metals:—Iron, ·114; lead, ·031; zinc, ·095; tin, ·054; copper, ·095; platinum, ·032; silver, ·057; mercury, ·033. But the specific heat increases at higher temperatures, and also varies with the physical state of a substance, whether liquid, gaseous, or solid. Another important truth is that the specific heat of a solid element varies inversely as its atomic weight; to produce the same change in temperature the atoms require equal amounts of heat (Dulong and Petit's Law).

As to the nature of heat, we are forced to the conclusion that it is a form of energy. When solids are converted into liquids, and liquids into gases, the heat absorbed is used in overcoming the cohesion among the molecules, and increasing molecular motion. When work is performed, say in overcoming frictional resistance, heat is produced. In fact all forms of energy tend to become transformed into heat, which is the least useful form of energy. A definite relation exists between mechanical work done and the amount of heat produced. Joule showed that the amount of heat required to raise 1 lb. of water, 1° Fahr., was equal to 772 foot pounds. This number, often represented by the letter J, is called Joule's dynamical equivalent of heat.

The subject of heat is dealt with in theoretical or practical aspects under **Annealing, British Thermal Unit, Calorific, Calorimeter, Expansion, Hardening, Heat — Transmission of, Tempering.**

Heater.—A lump of iron made red hot and laid on a piece of plated work to raise its temperature when a small amount of setting has to be done. The practice is bad. Also a similar piece of hot iron laid near a mould to dry it, or a portion of the same after mending up.

Heating Surface.—In estimating the value of heating surface in a boiler the usual practice is to take the whole of the areas exposed to the flame and hot gas on the one side and to the water upon the other. But all of these surfaces, it must be remembered, are not equally efficient as steam generators. Water is a bad conductor of heat. The parts which form the most efficient heating surface are those which receive radiant heat from the fuel. A clear non-flaming fuel, like coke, or a clear fire, is more efficient in heating than a flaming coal. Efficiency of heating surface diminishes with distance from the fire, hence there is no advantage in extending the lengths of furnaces, nor the lengths of smoke tubes, beyond certain limits. In the modern locomotive, increased heating surface is obtained by enlarging and lengthening the fire-box. Surfaces below the fire-grate and over the smoke flues of boilers are of little value.

The old egg-ended boilers were made of excessive length, sometimes 50 ft. or more, with the object of increasing heating surface. But though evaporative power depends on the efficiency of heating surface, it does not depend on

mere length or extent, but on its value. Increase in length, beyond a reasonable amount, results in danger, due to excessive expansions and contractions, with straining of seams, rips of plates, and grooving. These straining actions may even exceed the ultimate tensile strength of the metal. Another practical limitation to the length of boilers is that there is no advantage in increasing their length beyond that at which the gases will be capable of rendering up heat to the boiler. Beyond that length the boiler would radiate as much as it received.

Heating surface is related to grate area, because the quantity of water evaporated per hour depends on the quantity of fuel that can be burnt per hour. This again depends on whether natural or forced draught are employed.

The ratio of heating surface and grate area varies much. Neither heating surface nor grate area indicate the amount of evaporation possible, nor the quantity of coal that can be burned, unless they are taken in conjunction with like conditions. But if the nature of the draught used is known, the grate area is a fair indication of the power of a boiler, because the quantity of water evaporated per lb. of fuel does not vary much under equal conditions. The heating surface of various boilers in proportion to amount of grate area varies from about 20 to 1 in verticals, to 80 or 90 in locomotives. A 5-ft. Cornish boiler has a grate area of about 12 ft., and heating surface of 300 ft. An 8-ft. Lancashire boiler has a grate area of about 40 ft., and a heating surface of nearly 1,000 ft. The heating surface of vertical boilers is small in proportion to the grate area. The area of the fire-box also is large in proportion to the water space. Hence there is a strong tendency to prime in these boilers, owing to the violent ebullition set up. The heating surface of locomotives totals to from about 1,200 square ft. to 2,000 in some of the recent heavy engines. Of this the fire-box has from 120 to 170 ft., and the tubes the remainder. The fire-grate area ranges from 18 or 20, to 24 or 25 square ft.

The heating surface of the locomotive boiler is very large. Though the total surface is from fifty to seventy times the grate area, yet the fire-box has a heating surface of only about six times the grate area. Though only from one-tenth to one-twelfth is thus provided in the fire-box, it absorbs from one-half to one-third of the total heat of combustion.

Approximately with natural draught, the heating surface of marine boilers may be taken as about thirty-five times the grate surface.

The following figures relate to the grate area and heating surface of some typical water-tube boilers :—

Name of Boiler and Working Pressure in lb. per sq. in.		Grate Area.	Total Heating Surface.	Coal burnt per sq. ft. of Grate.
		Sq. ft.	Sq. ft.	Lb.
Belleville	242	757·6	21,593	25·68
D'Allest	213	1,076	37,201	30·72
Niclausse	213	783	23,240	24·53
Du Temple	199	76·4	2,682	61·03
Normand	199	35·7	1,894	67·85
Thornycroft	199	76	4,126	61·44

Heat—Transmission of.—The manner in which the transfer of heat takes place from the fuel on the fire grate to the water within a boiler occurs in three ways. Heat in passing from a hotter to an adjacent colder body, equalising the temperature of both, or changing their state, does so by the method termed *diffusion*. Heat is diffused in three ways; by *radiation*, by *convection*, and by *conduction*. Each of these processes is in operation in steam boilers; the first in the fire-box, the second through the flues and tubes, the third through the boiler plates.

In radiation, the heat travels in straight lines only, and is transferred from the hotter body to the colder through an intervening medium which does not itself become hot. It is only when the passage of the heat is stopped that any heating effect is exercised upon the body upon which it falls. Thus in winter the sun's rays warm the body upon which they fall, even though the air through which they pass is at a temperature below freezing. As heat travels in straight lines its efficiency is diminished by an increase in the inclination at which the rays fall upon a body. The amount of heat acquired by a body diminishes as the square of the distance increases. The radiation of heat is greatest in the fire-box of a

steam boiler. Solid incandescent fuel radiates more heat than flame, and flame more than hot gases. The latter scarcely radiate heat at all. The crown of a fire-box also receives more radiant heat than the sides.

Convection, or the passage of the heat through the flues and tubes, is not a direct form of transfer of heat like radiation and conduction. That is, the mere passage of heat through a tube does not raise the temperature of the water, but the temperature is raised by conduction. Convection, therefore, is merely a carrying of heat from one part to another; the gases are the carrying agents, bringing the heat from the furnace to be utilised by the relatively cold tubes by conduction.

Conduction is the flow, or passage, or transmission of heat through an unequally heated body, passing from the parts of higher to those of lower temperature, until the temperature is equalised throughout. The heat is transmitted through a boiler plate by conduction; the heat of the fuel, flame, or hot gas being transmitted through the plate to the water on the other side. The cleaner the metallic surfaces, the more homogeneous the material, and the more direct the application of the heat, the more perfect will be the conduction.

In considering the transmission of heat in steam boilers there are two different conductions considered,—internal and external, the former being the conduction through the thickness of the plate, the latter being the separate conductions of the inner and outer faces of the plate, or the absorption on the fire side, and the emission on the water side. The transmitting power of the plate diminishes with its thickness, so that a thick plate will conduct less readily than a thin one, but the difference in thickness will not be so material in diminishing conduction of heat as the external resistance will be. The temperature, greatest on the fire side, diminishes regularly to the water side; but only if the plate is homogeneous.

The expression for the quantity of heat transmitted through 1 square foot of plate per hour is as follows:—

$$Q = \frac{T - T'}{P \times t + H + W}$$

where Q = the quantity of heat units transmitted through one square foot of plate per hour.

T = the temperature of the hot gases.

T′ = the temperature of the water.

t = the thickness of plate in inches.

P = the coefficient of thermal resistance, found by experiment, and according to Peclet, ·0096 for iron, and ·0040 for copper.

H = the resistance to the absorption of heat by the face of the plate on the fire side.

W = the resistance to emission of heat from the face of the plate on the water side.

Numerous experiments have been made to ascertain the heat losses in boilers.

Mr A. Blechynden made a carefully conducted series to determine the transmission of heat through steel plates of various thicknesses from heated gas on the one side to water on the other. The plates employed in the experiment ranged from ¼ in. to 1⅛ in. in thickness. The experiments proved that in all the plates the units of heat transmitted per degree difference of temperature between the fire and the water was proportioned to the square of the difference between the temperatures at the two sides of the plates, or

$$\frac{\text{Heat transmitted per square foot}}{(\text{Difference of temperatures}) \times 2}.$$

In these experiments the plates were perfectly clean, but it is obvious that if plates become coated with bad conductors, such as scale, deposit, grease, the thickness of the plate then becomes comparatively immaterial.

Some experiments of Sir J. Durston's were directed to ascertain the loss of efficiency of the heating surfaces of boiler tubes, due to deposits of grease. An apparatus, Fig. 143, A consisting of a rectangular iron vessel *a* was prepared to hold the water, and was fitted with stuffing boxes *b* for the piece of tube under test, the heat being supplied from a horizontal Bunsen burner *c* placed internally. The mean of several experiments gave a loss of efficiency of 11 per cent., due to the presence of a thin layer of grease. He also mentions the case of the furnace crown of a boiler which came down

shortly after concluding some experiments in it in which greasy water was used. Further, in an experimental boiler in which many experiments were carried on to determine the temperature of tube plates, and other matters, and which was subjected to very severe treatment, no leakage occurred until after oil was introduced with the feed water. This produced leaky tubes, which a temperature of about 3,000° Fahr. in the combustion chamber, and the admission of cold air through the tubes after drawing the fire had failed to do.

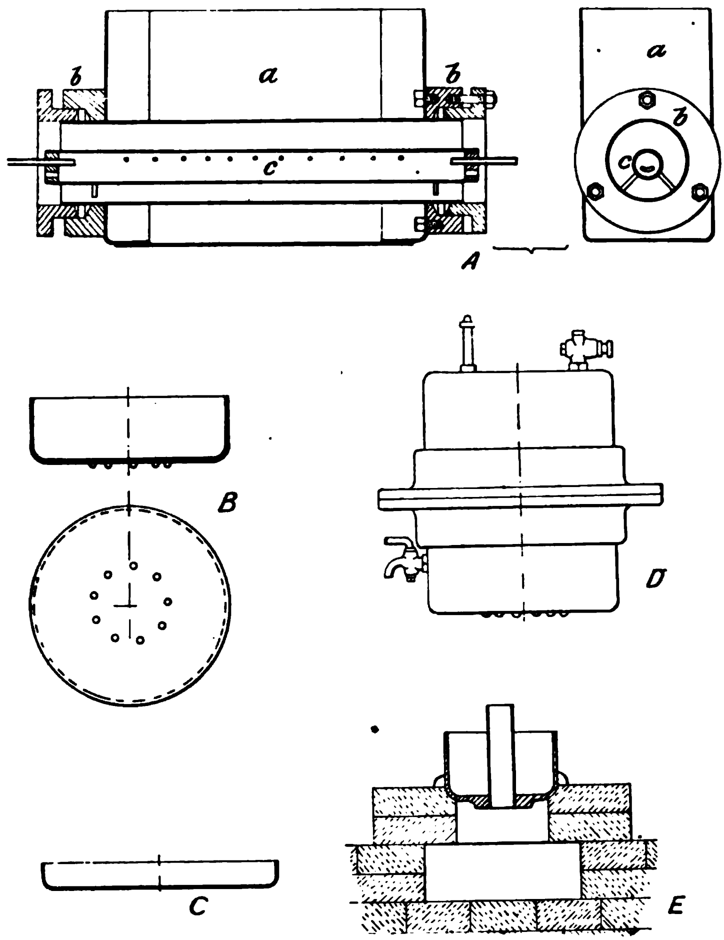


Fig. 143.—Experiments on Heat Transmission.

Some of Sir J. Durston's experiments were made to determine the temperature of the hot side of a plate, through which heat is passing to boiling water. A circular flanged dish, Fig. 143, B, was prepared, 10 in. diameter, by 3 in. deep, by $\frac{1}{4}$ in. thick, with eight pieces of fusible solder of different compositions attached to the bottom, and it was half filled with water. The water was boiled for some time over a Bunsen flame, with a temperature of about 1,500° Fahr. On examination of the solder it was found that those, the fusing points of which ran up to 240° had melted, but that the next which would fuse at 243° had only been slightly softened, thus fixing the temperature of the side of the plate exposed to the fire at about 240° Fahr. There was only $240° - 212° = 28°$ difference in the temperature of the fire side and the water side of the $\frac{1}{4}$-in. plate.

A layer of grease taken from the interior of a boiler was now spread over the inside of the vessel to a thickness of $\frac{1}{32}$ in., and the experiment was repeated. The melting of the fusible alloys now showed the temperature of the bottom of the plate to be 330° Fahr., being a rise of 90° Fahr., due to the layer of grease of $\frac{1}{32}$ in. thickness only.

Further experiments were made with another dish 24 in. in diameter, by $2\frac{1}{2}$ in. deep, by $\frac{1}{4}$ in. thick, Fig. 143, C, subjected to various temperatures, and filled with water mixed with other substances. The vessel was placed over a forge fire, and the melting of fusible alloys denoted the following temperatures:— With a moderate blast, and boiling fresh water, the temperature of the bottom of the vessel was, as in the previous experiment, 240° Fahr. With a higher blast, giving a temperature of 2,200° Fahr., the temperature of the bottom of the vessel was 280°. Adding mineral oil up to 5 per cent., and increasing the temperature of the fire to 2,300°,

the temperature of the plate went up to 310°. Using fresh water with $2\frac{1}{2}$ per cent. of paraffin, and with a temperature of 2,100°, the bottom of the vessel showed a temperature of 330°. With fresh water and $2\frac{1}{2}$ per cent. of methylated spirit, with the fire at 2,500°, the bottom of the vessel showed 300° of temperature. With a greasy deposit $\frac{1}{16}$ in. thick on the plate, and with the fire at 2,500°, the temperature of the bottom of the vessel was above 550° Fahr. These and other experiments demonstrated how greatly the temperature of the fire side of the vessel varied with the nature and thickness of the deposits.

These experiments were all conducted in open vessels, with the water boiling at atmospheric pressure. Another series was undertaken in a closed vessel with the water boiling at higher temperatures than 212°. A hooped steel vessel of 10 in. diameter, of $\frac{3}{8}$-in. plate was employed for the purpose, Fig. 143, D. With clean water, and clean surfaces, the following results were obtained. In two experiments there was a difference of 67° and 85·5° Fahr. between the temperature of the water and that of the fire side of the vessel. But with grease deposits $\frac{1}{16}$ in. thick on the bottom of the vessel inside, there were differences in temperature of 151° and 199°, the differences being due to the nature of the grease used. And when grease was spread up the sides of the vessel as well as over the bottom, there was a difference of 537°; an object-lesson on the dangerous effects of grease in producing overheating of plates. Other experiments showed that increasing the steam pressures did not make any marked addition to the excess of temperature of the fire side of the plate over that of the boiling water.

Dr A. C. Kirk made some experiments in order to determine the difference in temperature on the fire side and the water side of tube plates of various thicknesses. These experiments prove the wisdom of the limitation of the thickness of furnace tubes imposed by the Board of Trade, and Lloyds, and they prove also that tube plates should be kept as thin as possible consistently with the pressures they have to sustain. In one respect though, these experiments of Dr Kirk's do not realise the exact conditions that exist in a steam boiler, because they were performed in an open vessel; they nevertheless afford a sufficiently accurate guide from whence conclusions may be drawn as to the transmission of heat through thick and thin plates.

Fig. 143, E, illustrates the apparatus used. It consisted of a dish of malleable iron, $\frac{1}{2}$ in. thick, 11 in. in diameter, by 6 in. deep, with a thickened bottom into which a tube $2\frac{1}{2}$ in. external diameter was fitted by expanding in the usual way. Half-way into the tube and half-way into the bottom, plugs of lead, tin, and antimony were inserted in order to test the heat of the bottom by the fusing points of those metals. The bottom was made in the first place $2\frac{3}{4}$ in. thick, and the thickness gradually reduced by turning down after successive experiments The vessel was heated over a smith's fire, supported on brick-work, and the tuyere blast was used. At each experiment the vessel was exposed to the full heat of the fire for three-quarters of an hour.

Omitting the record of the experiments with the higher thicknesses, which have no counterpart in boiler practice, and neglecting also minuter details of the experiments, the following points are worthy of note:—

With the plate 1 in. thick, a tin plug melted, but lead did not, and Dr Kirk estimated the temperature on the fire side at probably 500°, the melting point of tin being 448° Fahr. This makes a difference in temperature of say $500° - 212° = 288°$. With the plate reduced to $\frac{3}{4}$ in., the tin plug did not melt, thus showing a temperature on the fire side lower than 448° Fahr. With the plate reduced to $\frac{5}{8}$ in., the melting of fusible alloys indicated about 360°. Reducing the plate to $\frac{1}{2}$ in., the melting of alloys indicated a temperature of 300° Fahr. Deducting $300° - 212° = 88°$ only in a $\frac{1}{2}$-in. plate, against 288° in a 1-in. plate.

With an increase in temperature on the water side, there would be a corresponding increase on the fire side. Taking a marine boiler pressure of 160 lb., the temperature of the water would be 370°; then $370° - 212° = 158°$ of temperature would have to be added to the above. So that with this pressure, the temperature on the fire side of 1-in. plate would

be $288 + 158 + 212 = 658°$, and the temperature on the fire side of $\frac{1}{2}$-in. plate would be $88 + 158 + 212 = 458°$.

In actual practice the difference may be greater on the two sides, because in the experiment made with one tube only, the water was in contact with the tube end the whole of the time; while it is believed that in steam boilers with crowded tubes the water is often driven away from contact with plates by reason of defective circulation.

These experiments prove that thin tube plates are preferable to thick ones, and the subject has a practical bearing not only on the transmission of heat, but on the freedom of the tube ends under extremes of temperature.

Many of the experiments which have been

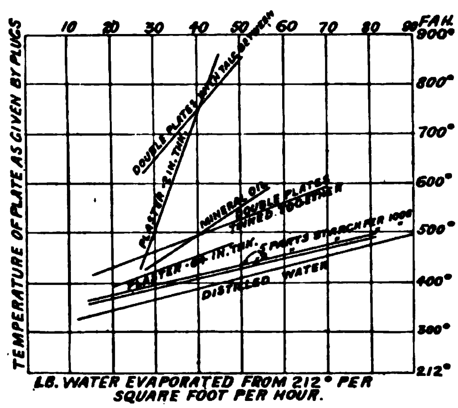


Fig. 144.—Experiments on Heat Transmission.

made in order to determine the conditions which govern the transmission of heat through metal plates have been carried out under circumstances which do not strictly represent what goes on in actual steam boilers, so that though conducted with great care, the value of the results as bearing on actual practice is generally open to more or less of question. But their general bearing is yet very valuable.

Some experiments made by M. Hirsch on the Continent to determine the conditions which govern the transmission of heat through boiler plates approached more to the circumstances which occur in actual practice than have many others undertaken with the same purpose. He made an experimental boiler, the bottom of which consisted of a piece of iron plate about 16 in. diameter, by full $\frac{3}{8}$ in. thick. The bottom of the plate was drilled to receive two circles of plugs of fusible alloy, each circle containing twelve plugs, the melting points of which varied from 230° to 842° Fahr. The bottom of the boiler was heated by means of a blowpipe flame of air and gas combined, and capable of regulation to produce any required temperature. The boiler was encased to prevent radiation. The temperature of the fire side of the plate was observed by noting which of the plugs fused, and the amount of heat transmitted was estimated by the quantity of water evaporated. Several different classes of experiments were performed with the boiler, and the results plotted graphically. Thus, to determine the influence of a thickened portion, such as a seam, a piece of plate $\frac{1}{8}$ in. thick was soldered to the bottom of the boiler, the surfaces being machined for the purpose. To represent the presence of cinder in iron, some finely powdered talc was interposed between the plates. In other cases starch was added to the water to thicken it, the plate was coated with plaster to imitate scale, and deposits were represented by coatings of oil, mastic, axle grease, and tar. The results are plotted in Fig. 144. The deductions which M. Hirsch drew from these experiments are as follows:—

(1.) That a sound plate well wetted on one side does not attain at any part a temperature high enough sensibly to affect its strength, even when exposed to intense heat. (2.) The water may become viscid to a considerable extent without rendering it incapable of keeping the plate well wetted, or notably reducing its power of cooling the same. (3.) As any doubling of the plate hinders the transmission, even a well-made riveted joint should not be exposed to intense heat. (4.) A flaw in the metal, or want of intimate contact at a joint in the part of a boiler exposed to any severe heat, constitutes a serious danger. (5.) Contact with very hot brick-work is in no way dangerous, so long as the inner surface of the plate is well wetted. (6.) Any coating of grease deposited on the inner surface of the plate greatly hinders the transmission of heat. (7.) Should the greasy coating consist of a substance liable to decomposition by heat, overheating is specially to be

feared. Greases of organic origin, such as linseed or colza oils, &c., are in this respect much more dangerous than mineral oils.

Heat Treatment.—A term which has been employed very much of late years to signify a certain class of researches which have been prosecuted in regard to the effects of heat applied in varying degrees to steels. Though the working of steel, and heat treatment have always been inseparable, the term denotes the scientific rather than the workshop methods. The names of Brinnel, Chatelier, Campion, Sauveur, Stead, Roberts-Austen, Osmond, Hadfield, Harbord, and others, with those of the microscopists, are familiar as workers in this field. It is rather difficult as yet for the practical man to assimilate the results of these researches, but it is certainly very interesting to gather facts here and there which have a direct bearing on results that are well known, if not clearly understood in the shops.

Brinnel's researches went to prove that as fineness of grain in steel coincides with strength, and coarse structure with weakness, the aim should be to secure fineness by heating within a certain range of temperature. The object is to cause the carbon to pass from the *cement* variety Fe_3C, of coarse structure, a carbide, to the *hardening* variety, a hydrocarbon of fine grain. These distinctive terms are due to Rinman (1865). Brinnel showed that only within a particular range of temperature could the steel be heated for it to receive the finest structure, which he denoted by the letter W. The softening temperature, or that at which the change takes place from the hardening to the cement form he denoted by V. These temperatures are now known as points in the heating and cooling curves of Ac_1 and Ar_1 respectively. The point V, or Ar_1 is the first recalescence point, which varies with the carbon content, from 620° C. to 700° C. The critical heating temperature Ac_1 is about 30° higher. Hence steel should be heated to that amount before quenching, but for tempering it should not exceed the point Ac_1. If this temperature is exceeded the steel becomes brittle; if it has not been reached the hardening will be incomplete. If heated to any temperature above W or Ac_1, the carbon is always present in the hardening form. When steel is heated to any temperature between V and W the carbon passes from the cement to the hardening form.

Steel, whether hardened or unhardened, when heated to the temperature W loses any previous coarse crystallisation, and becomes fine in grain. The only exception is burnt steel. Also, after being heated to W, if it is allowed to cool slowly, it retains its fine structure; or if it is suddenly cooled from the temperature W, it retains the fine structure, and is fully hardened. But if a piece of steel, whether hardened or unhardened, is heated to a temperature above W and allowed to cool slowly, its crystals increase in size until the temperature V is reached, after which there is no further increase. Hence when a piece has been heated above W, and is then allowed to cool to W, and quenched, though it will be fully hardened, its structure will be coarser than as though it had been quenched from W without having been previously heated above that temperature. Also, the higher the temperature above W from which the steel is allowed to cool regularly the larger is the crystallisation; and the slower the cooling from a temperature above W the larger are the grains. When a piece of steel is heated to a temperature below W, some of its hardening carbon is changed into cement carbon, with softening of the metal.

The heat treatment of pure carbonless iron has also been studied, notably by Mr Stead. He found that heating pure iron to between 600° and 700° C. caused fine grain to develop coarse crystallisation. The duration of the process is important, since given sufficient time, the angles of the axes of many different grains change their positions until they become of the same angle. A coarse grain might give more strength than a fine-grained iron.

Hectare.—A measure of surface equal to 100 ares. The are is the unit of surface measure in the **Metric System**, and is equal to 100 square metres, or 3 square poles, 28 square yards, 7·68 square feet. 40·4671 ares equal 1 acre, and hence 1 hectare = 2·471143 acres = 2 acres, 2280·3326 square yards = 2 acres, 1 rood, 35 square poles.

Hectogramme.—A measure of weight

equal to 100 grammes. *See* **Metric System**, and **Gramme**.

Hectolitre.—A measure of capacity equal to 100 litres. *See* **Metric System**, and **Litre**.

Hectometre.—A measure of length equal

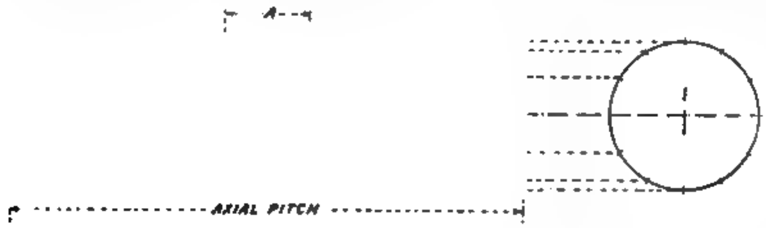


Fig. 145.—The Principle of Helical Gears.

to 100 metres. *See* **Metric System**, and **Metre**.

Heel Tool.—A hand-turning tool for metal rudely resembling in shape that of a boot. The heel being supported on the rest, and the handle on the workman's shoulder afforded great power for manipulation.

Helical Gears.—These are essentially screw gears, though the fact is disguised by the extremely short proportion which the length of the teeth bears to the helices of which they form a section. Hence the helical gear may be considered as a slice cut out of a many-threaded helix, perpendicularly to the axis. In a single helical wheel the threads are of one hand only, in a double helical they are of both hands, the right and left spirals meeting in the middle plane of the wheel A, Fig. 145.

The advantage which these gears possess is that they engage without sliding friction, the action being that of rolling and pressure only. In ordinary gears, rolling occurs only for an instant at the pitch point. During approach and recess the teeth slide over one another. The old stepped wheels were designed with the object of reducing the sliding action. By stepping the teeth the total amount of sliding was divided equally among the steps. The effect was identical with that of reducing the pitch and increasing the number of teeth, but without the loss of strength which this would involve. If the angles in a stepped gear are obliterated, the helical gear with an infinite gradation of steps will result.

The objection to the single helical gears is that the pressure takes place in a diagonal direction. This is of no moment when duties are light, hence they occur in the back gears of many Continental lathes. They are, moreover, easily cut. But in double helical gears the pressures are opposite and equal to each other, and these are invariably employed for heavy work.

The axial pitch of the primary helices (Fig. 145) is of no moment from the point of view of design. The important point is that teeth in mutual engagement shall have the same angle irrespective of the diameters of the wheels. And there is no constant angle for all pitches, and all wheels of varying widths of face. It is usual to impart enough angle to permit one pair of teeth to commence engagement before the previous leaving pair have quitted contact. In other words the *lead a* of the teeth (Fig. 145)

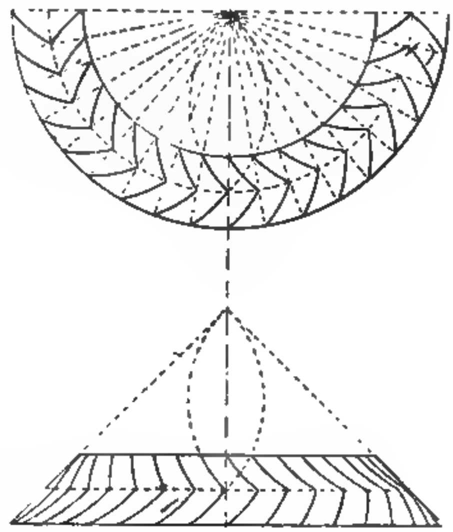


Fig. 146.—The Principle of Helical Bevel Gears.

should exceed the pitch slightly, by say one-fourth or one-third. An average angle of about 110°, *b*, between teeth will meet most requirements. To ensure interchangeability, all spur wheels of the same pitch and width should have the same angle. In Fig. 145, *a* is the circular

pitch, *c* is the normal pitch. The tooth shapes are taken on *c*. Helical bevel wheels have their teeth drawn as sections of screws developed on the pitch cones, as by the movement of a point along a rotating cone.

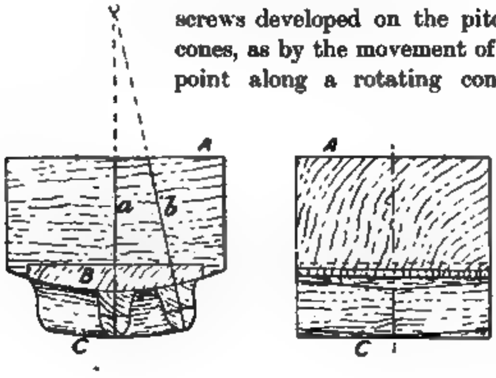


Fig. 147.—Block for Helical Spur Gear.

In double helical bevels the screws described will be right and left handed, Fig. 146.

The primary helix is used as the basis of reckoning. But the angles of the threads (and teeth) must change with the length of the teeth, exactly as they do in propeller blades, worm threads, and screw gears, &c. This must be taken account of in marking out and working the teeth, otherwise errors will result.

Double helical gears are mostly made from tooth blocks in wheel moulding machines. Patterns, except when large numbers are required off them, are costly, and cutting is also expensive. There are two methods of making tooth blocks. In one they are solid, in which case the machine must have provision for withdrawing spurs horizontally, and bevels at the angle of the teeth. *See* **Gear Wheel Moulding Machines**. But for the most part tooth blocks are divided in such a way that they can be withdrawn in detail, partly by machine, partly by the hands. There are different ways of doing this, the essential being the fitting of each portion of the teeth on each side of the middle plane to a backing, the latter being bolted to the machine carrier. The jointing is by dovetails, so that the parts cannot shift in relation to each other. Besides the advantage of ready withdrawal there is the further one that ramming, nailing, and venting can be done more readily when the teeth are divided than if in one piece. The making of a pattern block for a spur wheel is in brief as follows :—

Fig. 148.—Block for Small Pinion.

The backing piece, Fig. 147, A, is planed to its correct cubical dimensions, and a strip, B, is fitted into its front face and divided in the middle plane, and all are planed flush and square. The front blocks may be thick enough to include the teeth, or these may be fitted subsequently; we illustrate the latter. A centre line, *a*, is scribed round three faces of the combined block, and a radius, *b*, struck, corresponding with the radius of the wheel at the base of the teeth, and the

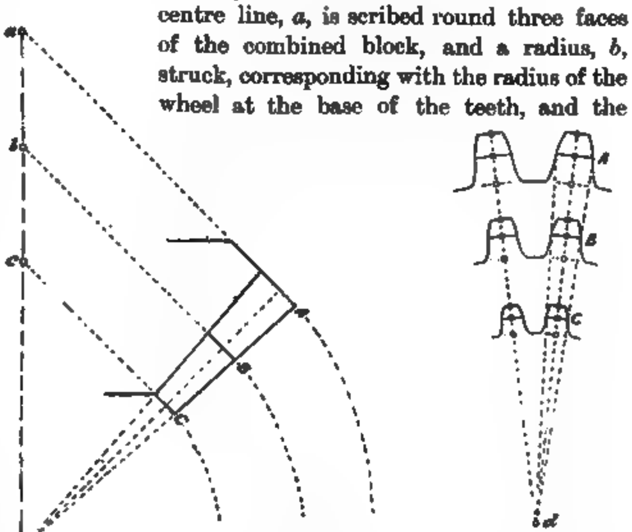


Fig. 149.—Development of Tooth Shape on Helical Bevel Wheel.

sweep worked. Blocks, C, are fitted and glued for the teeth, dressed off flush, and the teeth marked out on outer and joint faces from the

wheel drawing. This marking gives at once the angles at points, bases, and pitch plane. The lines representing the points must be drawn across the face of the block, connecting the ends, either by bending a steel strip, or by dividing the

Fig. 150.—Block for Helical Bevel Gear.

distances between faces and edges into equal parts and drawing lines through them. A templet is used as a guide for cutting the tooth spaces, for which chisel and gouge will be used. Pinions are often jointed as at *a*, Fig. 148, because of undercut on the lines *b b*.

Blocks for helical bevel wheels must have the relations common to all bevel gears, *see* **Bevel Gears—Machine Moulded**. Beyond these relations, there is the jointing, which is done on the same lines as spur blocks, modified by the bevelled form. The tooth shapes must be marked on the ends, and the middle plane, and the helical twist be marked across the tooth points. The drawing, Fig. 149, shows the development of these relations, and Fig. 150 their application to the tooth block. The teeth are marked on the faces A, B, C, Fig. 149. To ensure accuracy, the helical shapes should be marked and worked on three faces—points, pitch plane, and roots—the radii being taken from *a*, *b*, *c*, and to do this involves jointing the teeth temporarily in the pitch plane, and making them detachable from the block, which can be done with fine screws, the joints to be finally glued after the shapes have been marked. The tapering forms of the teeth preclude the use of a templet, as employed with spur teeth.

The ramming of the lower teeth is done before that of the upper, the latter being temporarily removed for convenience. After ramming, the hinder block is lifted by the carrier of the machine, leaving the teeth in two sections, to be withdrawn by the hands of the moulder.

The group of Figs. 151-153 on Plate IX. shows some very fine examples of helical gears cast by Messrs P. R. Jackson & Co., Ltd. The first gear-wheel moulding machine made was designed by the pioneer of this firm. Some of these gears are for service in rolling mills, which explains their massive proportions.

A peculiar type of helical gear is that in Fig. 154, which may perhaps be best described as a quadruple helical. These gears are produced by cutting, by Citroën, Hinstin, & Cie. (Paris). Ordinary double helical gears are also cut by the firm, thus obviating the necessity of cutting two half wheels and bolting them together. The quadruple teeth are apparently designed on the principle that you cannot have too much of a good thing. On the other hand, increasing the number of diagonals demands the greatest accuracy in cutting, and in fixing the wheels in order to secure proper meshing.

Helve.—The old trip hammer of the iron forges, still retained in some places. It derives its name of *trip* from the action of the revolving

Fig. 154.—Helical Gears.

cams or wipers, which trip or lift the hammer when they come in contact with it, the hammer falling by gravity. There are four wipers on the revolving cylinder, the rotation of which is timed to give about one blow a second. The helve ranges from 30 cwt. to 10 tons in weight,

PLATE IX.

Fig. 131.—Group of Six Sets of Massive Double Helical Gears, Cast in Steel.

Fig. 152.—Group of Double Helical Gears.

Fig. 153.—Pair of Heavy Roll Pinions in Cast Steel.

To face page 172.

and is pivoted. The terms *nose*, *belly*, and *tail* denote the position at which the wipers lift, the nose or *frontal* helve being most common.

Hemp.—Used in the form of tow, is employed in foundries for winding on small core bars to hold the loam. Also for temporarily closing exposed portions of moulds, to prevent sand getting into them while work is being done on other portions of the mould. *See also* **Ropes.**

Hexagon.—A hexagon is a six-sided figure. It is a regular hexagon if all the sides and all angles are equals; irregular if they are unequal. Geometrically a hexagon may be drawn by the general method of describing any regular **Polygon** or by the methods shown in Figs. 155, 156.

To construct a hexagon on a given straight line, A B, Fig. 155. With A as centre and radius A B describe arc B C, and with B as centre and same radius describe A D. With *o* as centre and same radius describe the circle, and from C and D with same radius cut off E and F. Join the

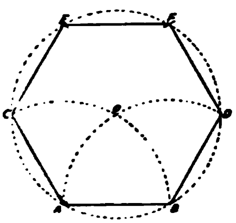


Fig. 155.

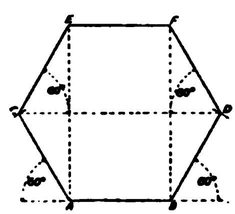


Fig. 156.

Hexagon.

points to complete hexagon. Thus the radius of any circle stepped off six times on the circumference gives the points of a hexagon.

The same problem may be done with the set-square of 60°, Fig. 156 :—Produce A B both ways, and draw A C, B D making angles of 60°; make A C, B D = A B. Erect perpendiculars A E, B F, and at C and D make angles of 60° with C D, producing C E and D F until they cut the perpendiculars. Join E F. If a circle is struck of the diameter of a hexagon over the flats, the hexagon can be drawn with a 30° and 60° set-square, without division, round.

High Potential—High-Pressure Electric Currents.—A term used to distinguish electric current of the higher E.M.F. which is used for transmission of power. The practical limit of pressure for transmission by insulated cables laid underground is about 6,000 volts, above this the expense of insulation prohibits the use of cables. Overhead lines of bare conductors carried by insulated supports can, however, be worked at very high pressures.

Transmission lines at pressures up to 50,000 volts are in successful operation. Alternating current can be generated at 20,000 volts. Then for overhead transmission the distance to be covered in miles, divided by 3, gives the number of thousands of volts for transmission which will be most economical of copper. For example, if it is required to transmit 500 HP. 60 miles, then :—

$$\frac{60}{3} = 20{,}000 \text{ volts}$$

$$\frac{500 \times 746}{20{,}000} = 18\cdot6 \text{ ampères,}$$

and conductors large enough to carry that current would transmit the 500 HP. If the distance, or the HP. were greater, and the generation pressure less, "Step-up Transformers" would be used to bring the line pressure to a suitable value. Wherever large areas have to be covered by electrical power supply, alternating high potential currents are used for transmission, and may be locally transformed down, or be rectified to direct current as required. Two instances will illustrate the application of each system.

The South Wales Electric Power Co. transmits electric power by underground cables to collieries, ironworks, &c., in its district. The line pressure is 3,000 volts, 2-phase. For underground work in collieries this is transformed down to 300 volts, whilst for surface work 600 volts is much employed. But in numerous instances for large induction motors in ironworks, &c., the full pressure of 3,000 volts is applied direct to the machines.

The London County Council produce at their generating station 3-phase current at 6,000 volts. This is transmitted by underground cables to sub-stations in the various districts. Motor generators installed there receive the high pressure alternating, and deliver continuous current at 550 volts, which is applied to the working of the electric tramways in the neighbourhood of the respective sub-stations.

Other methods of distributing and utilising high potential currents are treated under

Power Transmission Lines, Rectified Current, Transformers, &c.

High Pressures.—The term "high pressure" is as much relative as particular. The high-pressure cylinder of the compound steam engine is the cylinder which takes steam direct from the boiler; the low-pressure cylinder, *per contra*, being that which rejects steam to the atmosphere or condenser. A high-pressure engine is a non-condensing engine, the term having arisen at the time when all engines worked with steam at atmospheric pressure exhausted to a condenser, and Trevithick used steam of 50 lb., exhausted to the atmosphere, and therefore high pressure by comparison. Colloquially, high-pressure steam is that of more than ordinary pressure, and the term has been applied to steam of 30 lb., 50 lb., 80 lb., 100 lb., 160 lb., and perhaps to-day 200 lb. or 250 lb., will be understood as somewhat high. A condenser pressure of 5 lb. similarly is high where men are aiming to get down to 2 lb., or even to 1 lb., of absolute pressure in the condenser. So with compressed air; while 60 lb. is a usual pressure in industrial work, a torpedo is worked with air compressed to the "high pressure" of 1 ton per square inch, and where 700 to 1,000 lb. is usual for hydraulic pressures, any seriously greater pressure comes under the "high-pressure" terminology.

In theory, high pressures can usually be shown to be associated with economy, but they require a higher order of material, workmanship, and attendance, and in steam work the heat loss from a unit of area is greater than with lower pressures. The theoretical economy may therefore easily be changed into a practical loss, and ill-considered schemes for high-pressure work must not be expected to show their theoretical economies.

High pressures in the steam engine are economical under suitable conditions, because such steam is hotter, and permits of greater expansion, working between wider limits of temperature. The economy of high pressure, however, is much less than mere theoretical thermodynamic considerations would make it, for there is increased leakage to fight against, and the loss of heat by radiation is greater, as stated. This loss is guarded against by superheat.

The term "high pressure" is of wide application. The initial compression in the Diesel engine to 500 lb. is high as compared with the compression used in ordinary gas and oil engines, while "power" gas for the carbonic oxide variety will stand a compression that is high, as compared with that to which gases richer in hydrogen may be subjected.

High-pressure gas lighting uses gas (usually mixed with air) at a pressure of several inches, and even as much as 4 feet of water gauge. The light given by the incandescent mantle is very largely increased thereby.

In electrical work "high pressure" signifies a high voltage, which again demands the best of insulation, and the term, not long since applied to voltages of 10,000, is now bidding fair to be even inapplicable to such tensions as 60,000 volts, for even higher tensions are contemplated.

High Breast Wheel. — *See* **Water Wheels.**

High-Speed Bearings.—*See* **Bearings.**

High-Speed Engines.—A class of engines the great development of which is due to the demand for direct coupling of engines to dynamo machines. The older, comparatively slow engines drove through belting, a system which is now obsolete. Another cause of their development is in connection with torpedo boats. The 250, 300, or 350 revolutions a minute of these engines would be of little value but for the fulfilment of two other conditions; the governing within 2 or 3 per cent. at maximum load, and the ability to run from six to twelve months without stoppage for lubrication and cleaning, or repairs. The best high-speed engines fulfil these requirements without a hitch.

Objection has been made to the term "high speed" because the piston speed of long stroke mill engines is often higher than that of the small engines of short stroke. The terms "rapid rotating" and "quick revolution" have been proposed in place of it.

There are many varieties of high-speed engines, but the two which have the greatest vogue are the Belliss' double-acting, forced lubrication type, and the Willans' single-acting, constant thrust, splash lubrication type. Such engines must almost of necessity be enclosed, and have a suitable tank in the base plate to

receive the large quantities used, which are drawn in by the pump to be used again. Hence the Willans & Robinson, and the Belliss, the pioneers in this work, were enclosed from the beginning.

The Belliss Engines.—These (Figs. 157, 158) are used largely in central stations for the generation of electricity for lighting, power, and traction purposes. Their leading features are—complete enclosure, perfectly automatic lubrication, good balancing, simplicity of slide-valve and governor arrangements, durability under continuous service, and moderate number of working parts. Some of these engines have run for many months continuously, no addition to the oil supply being required, and without sensible wear of working parts. The wear of some portions after from two to four years of service has been but $\frac{3}{1000}$ in. or $\frac{4}{1000}$ in., a result which is mainly due to the system of lubrication, in which mineral oil at a pressure of 15 lb. to the square inch is forced into the bearings.

Messrs Belliss & Morcom are the pioneers in the application of forced lubrication to double-acting engines, having introduced the system in 1890. These engines are built in compound and triple expansion types. The cranks are set opposite to each other in the compounds, and by admitting the steam simultaneously at the top of one cylinder and bottom of the other, the reciprocating parts are to a large extent balanced in one direction. This also simplifies the single slide-valve design, which serves both cylinders, and is ground into its seating with ample bearing surface, which hardly wears in long service. The engine is governed with a shaft governor connected to an equilibrium throttle valve, and the governor gear can be adjusted through a wide range of variations while the engine is running. A variation of speed not exceeding 3 per cent. between full load and no load is guaranteed. If desired, a variation of not more than 2 per cent. momentarily with the whole load suddenly removed is guaranteed, and 1 per cent. permanent; but this involves a higher cost.

The arrangements for lubrication are the most interesting feature of these engines. The main casting forms a tank in which a pump is immersed. It has no valves or packings; but its oscillations, worked off the eccentric, fulfil the action of valves on a surface at the bottom of the pump. The oil is drawn from the bottom of the casing through strainers, which can be removed, and thence into pipes which lead to all the bearings. The casing is fitted with a door at the back, and the entire front can be removed, if necessary, to get at the working parts. As the cranks are not immersed in oil, no splashing occurs, which is an advantage if the engines are running when the doors are open. A compound engine of 150 HP. can be run for twelve months, making 3,188 working hours; and using only four gallons of oil in the crank chamber, being at the rate of $\frac{1}{100}$ of a pint during each working hour.

For the higher steam pressures of 125 lb. and upwards, the triple expansion engines are better than the compounds, being less liable to vibration at high speeds, and more economical.

The Willans' Central Valve Engine.—This is a unique design, in which cylindrical or piston valves move within the piston rods, or *trunks*. It is also a single-acting engine, the working stroke being the down stroke. It is arranged as simple, compound, and triple expansion; and the latter can be used as compound, or simple, without removing the compounding cylinders, by disconnecting their pistons and piston valves. This is due to the arrangement of the cylinders in tandem, with the high-pressure (or simple) engine lowermost, the intermediate above, the smallest uppermost, see Fig. 159.

The engine is surmounted by the steam chest, admission to which is controlled by a governor on the crank shaft, operating on the throttle valve directly; the steam after first passing through a separator, enters the upper piston rod through holes provided, and out into the cylinder by ports situated lower down. The piston valve closes these latter ports at about three-quarters stroke. The point of cut-off can be regulated by the vertical adjustment of *gland rings.* This point is usually determined and fixed by the pressure, &c., but it can be made variable, with different mechanism. Just before the piston reaches the bottom of its stroke, a lower valve uncovers ports, which allow the steam to pass from the upper to the lower side of the

Fig. 157.—Belliss Engines (Compound).

Fig. 158.—Belliss Engines (Triple Expansion)

piston, and away to the exhaust. The space below the piston is in communication with the exhaust chamber and exhaust pipe.

In the compound, and triple expansion engines the cycle of operations is practically the same as regards the movements of the valves, and are provided with *guide pistons*, one below each engine. These on the up-stroke compress the air contained in the guide cylinders. The amount of cushion is regulated to suit the intended speed, being increased with increased speed, and so preventing knocking. The work

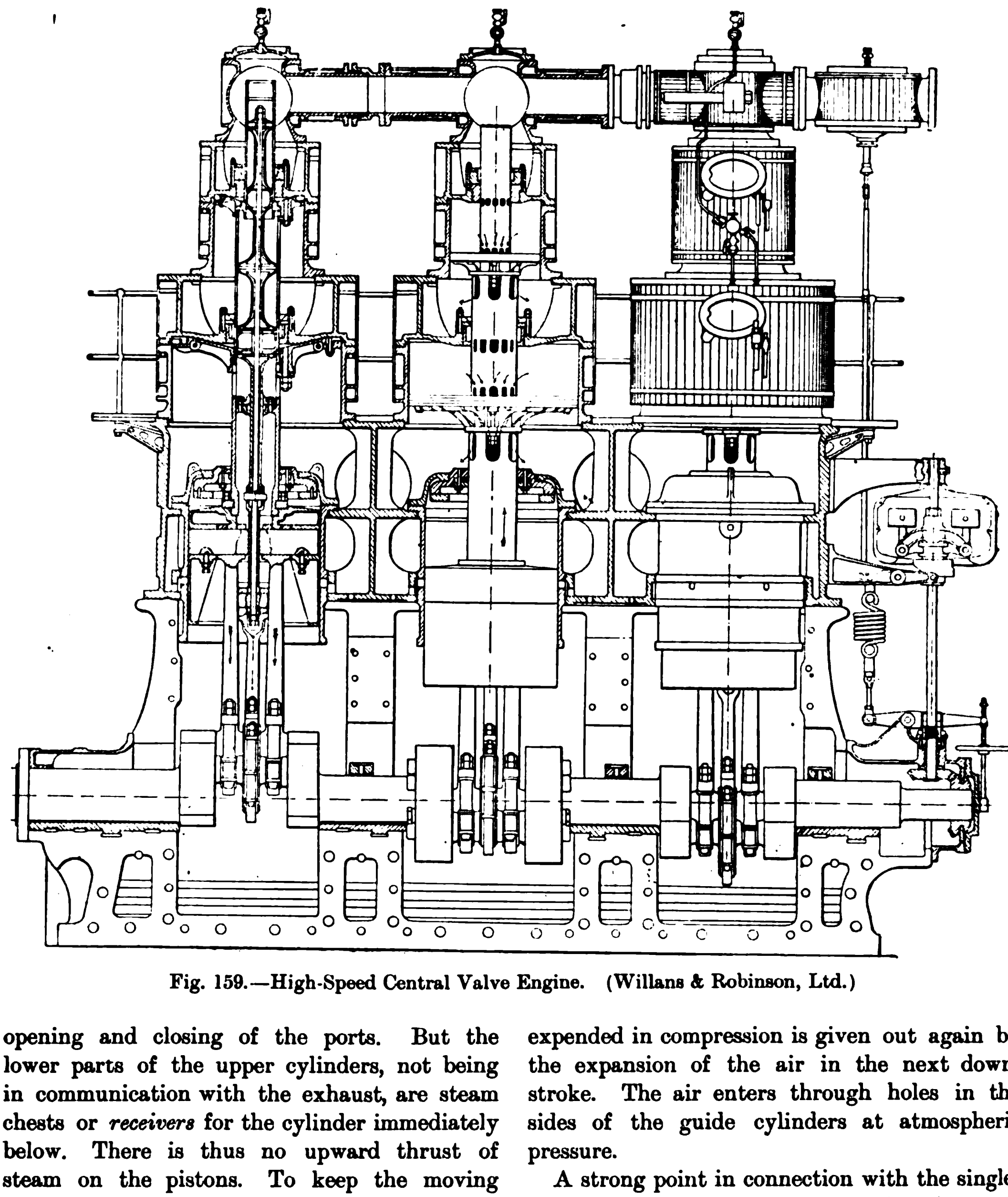


Fig. 159.—High-Speed Central Valve Engine. (Willans & Robinson, Ltd.)

opening and closing of the ports. But the lower parts of the upper cylinders, not being in communication with the exhaust, are steam chests or *receivers* for the cylinder immediately below. There is thus no upward thrust of steam on the pistons. To keep the moving parts in compression upon the up-stroke without excessive cushioning, the Willans engines expended in compression is given out again by the expansion of the air in the next downstroke. The air enters through holes in the sides of the guide cylinders at atmospheric pressure.

A strong point in connection with the single-acting working stroke is that the thrust is always downwards during the downward move-

ment under steam, and the upward by cushioning. Hence as there is no reversal of pressure, there is freedom from knocking. Caps are not used on the crank shaft bearings, nor double brasses on the connecting and eccentric rods. The lubrication of the cranks and journals is effected by the dipping of the cranks in a bath in the crank chamber containing a mixture of oil and water. Lubricators of the sight feed pattern are put on the cylinders. The drainage of water from the cylinders is facilitated by the vertical position, by the rush of steam through the exhaust ports, and the dished form of the pistons. It is going on during the whole of the exhaust stroke. The wear on these engines is very small. After years of running it is scarcely measurable.

High-Speed Lathes.—The evolution of the type of lathe required to stand up to the stresses imposed by the tools of high-speed steel has proceeded on two main lines. There is first the remodelling of the old belt-driven head, and second the production of a new type—*the all-gear head*—without stepped cones. Both give the results desired. Whether one or the other should ultimately survive, the fact is clear that the old lathe with small cones, narrow belts, and small range in speeds will soon be no longer made.

There is no special difficulty in designing a lathe for the new steel tools. But that at present has to be often combined with provision for utilising the old carbon steels, the slogging, and the fine finishing in combination. The two conditions do not harmonise. In designing lathes for the new steels they have to be both speeded up, and made stronger to absorb much more power. But lathes to combine both classes of work require these features, in addition to the moderate speeds with less power for dealing with the carbon tool steels. The question of back gear is affected, because while in the ordinary lathes the higher power gained by back gear is required at the slower speeds, in the new lathes the higher power is also wanted at the higher speeds. A combination lathe must therefore combine an extensive range of speeds from very slow to very fast, with back gear for all, when required. The ordinary headstock does not fulfil these conditions.

It was soon obvious to lathe makers that the mere enlargement of cone pulleys and the use of wider belts would not alone fulfil the requirements. Even if sufficient power were obtained, which was difficult, the large range of speeds could not be obtained by belt shifting, with the old proportions of cones, and single back gears. The problem of making lathes with greater range in regard to speeds, to absorb from six to ten times the HP. of the older lathes, explains the radical character of the remodelling that is going on, and which affects all parts of the lathes. When these came in they were dubbed *big-headed* lathes, but that term is not so appropriate now. The enormous strains in cutting, amounting often to several tons of pressure on the tool, has led to remodelling also of the loose poppet, the rest, and bed; and here, too, variations occur in design.

The headstock bearings have to be increased, and when hollow spindles are used, they become of an abnormal diameter and length. In a 10¼-in. centre lathe by Smith & Coventry the front bearing is 4 in. diameter, by 6 in. long. A 10½-in. lathe by Darling & Sellers has a front bearing 4½ in. by 6½ in. In a 12½-in. lathe the front bearing is 5 in. by 7½ in. One of Miley's, of 12-in. centres, has a bearing 4½ in. by 7 in. A lathe by Dean, Smith, & Grace has its front bearing 10 in. by 14 in.

The two features which are characteristic of the high-speed heads are the use of back gear on high speeds as well as low, and when stepped cones are retained, the great enlargement of the cones, and a very small range of speed between the cone steps. In a modern lathe of this type the smallest step is larger than the largest in the older lathes, and there are but slight differences in the diameters of each step. Unless this is observed, the range of speeding obtained will not be small enough in each step. Speed gears are introduced in the cone-pulley design of lathe, to give in combination with the steps the large range desired. In those designs in which the cones are abandoned, a simple fast and loose pulley is used, or a single pulley only, and all speeds are obtained through change gears alone.

The objection to the stepped cones is that they must be run at high speeds to obtain the

power required, and that on the largest steps giving the slowest speeds, the power is less than it should be. Hence the substitution of the all-geared head with single-driving pulley.

In all modern lathes an object sought and practically obtained is to have all the steps in a range of speeds in approximately geometrical progression. How the foregoing conditions are worked out are indicated in the examples selected for illustration.

The Hetherington head, Fig. 160, is an all-

Fig. 160.—All-Gear Head. (John Hetherington & Sons, Ltd.)

gear head, driven by fast and loose pulleys situated above the gear box, driven by a belt at constant speed on the pulley A, the loose pulley adjacent being of smaller diameter to relieve the strain on the belt. The belt drives to an idler shaft through gears, by which a wheel, B, on the headstock spindle is driven. On the spindle to the rear there are four wheels of graduated sizes, with which four others, C, C, C, C, on the shaft parallel therewith engage, but run loosely. Either of these is put into engagement by a hand-wheel D operating a sliding key in the bores. There are also three back gear wheels on the hinder shaft operated by a lever and clutch jaws, and engaging with wheels E, F, G. There is but one clutch with a set of jaws on each end, and one on the periphery. The result is that while either one is in, the others must be out of engagement. A range of twenty-four spindle speeds is obtained, twelve for high-speed work, and twelve for slower speeds. The spindle speeds are:—3·42, 4·0, 4·69, 5·5, 6·81, 8·0, 9·4, 11·07, 13·65, 16·0, 18·75, 21·1, reducing speeds; and 37·5, 44·2, 54·6, 64·2, 75·0, , 128·4, 150·0, 176·8, high ıese lathes are extremely nd will stand up to any lestroy them.

, Plate X., illustrates a e lathe in which these gears ıed, but a motor drive is for the pulleys in Fig. 160. eness of the design is a nterest. A portion of the ıed as a tank for the lubri- slots are planed in the top for locking the slide rest carriage and also the movable poppet, four clamping bolts being used in each. The geared poppet with set-over fitting will be ınd also provision for its ılong the bed by rack. Its asures 7 in. in diameter. The spindle of the headstock is bored up to form an oil or grease supply for its bearings; the front neck measures 10 in. diameter by 15 in. long. It has a gear ratio of 20·36 to 1 for heavy cutting, and one of 166·03 to 1 for finishing and screw cutting. It takes approximately 60 B.H.P. for cutting on a diameter equal to the height of centres, at 100 ft. per minute, and 30 B.H.P. for cutting at 50 ft. per minute. The lathe bed measures 30 ft. in length, 3 ft. 7½ in. wide over the top face, and is 2 ft. deep. It takes 18 ft. between centres, and the lathe weighs 30 tons. The feeds are 32, 16, 8, and 4 cuts per inch of traverse for either sliding or surfacing. They

PLATE X.

Fig. 161.—Hetherington Motor-driven High-speed Lathe.

Fig. 162.—Motor-driven 30-Inch High-speed Lathe. (Hulse & Co., Ltd.)

To face page 180.

are effected through cut gears, changed by an index lever while the lathe is in motion. There is a quick withdrawing motion for screw cutting, which disengages the gun-metal half-nut from the lead screw. The length of this nut is four times the diameter of the guide screw.

Messrs Hulse make an all-gear head driven either by a fast and loose pulley, or by a motor. It has single, double, and treble gears, giving twenty-four speeds with one countershaft speed. Eight are obtained in single, and sixteen in treble gear, and there are no idler gears running at any time, which reduces noise, and wear, and tear. The gears on the main spindle form a nest, which are put into engagement by a rotating frame that carries a sliding gear, and which by combined sliding and rotating can be put into mesh with either of the nest of wheels on the main spindle. The drive to this takes place through second and third motion shafts, carrying pinions. The second motion shaft derives its movements from the pulley shaft, or the motor. This provides for single-gear drives; the double and treble are effected by sliding back gears driving directly to the face plate.

Fig. 162, Plate X., illustrates a large lathe of 30-in. centres made by this firm specially for turning heavy marine, and other shafting. It has two carriages, each with two compound top slide rests. A 10 HP. motor is provided for moving the rests rapidly and independently of the feeds, effected in the usual way. A 60 HP. motor drives the headstock. The gears provide for two changes in treble, and four in quintuple drive, giving spindle speeds ranging from one to sixty revolutions a minute, all affected by sliding the gears. The loose poppet has a spindle 7 in. diameter, actuated by worm gear. The back thrust of the poppet is taken by a ratchet rack within the bed. A rest is fitted at the front for facing the ends of shafts. The transverse slides on the main carriages of the rests can be operated simultaneously, or independently from the front of the lathe. The motions are derived from a central shaft, driven from the headstock by gears, or clutched into gear with the 10 HP. motor mentioned, for quick adjustments. The motion of this shaft is transmitted by a cross shaft to rotating nuts on fixed lead screws at each side of the bed. A large range of feeds are obtainable, varying from $\frac{1}{32}$ in. to $1\frac{1}{2}$ in. traverse. Taper turning can be done through change worm wheels.

Fig. 163, Plate XI., represents a 12-in. centre lathe working on steel forgings at 80 ft. per minute. The large belt cone diameters will be noted, these ranging from 13 to 28 in. by $4\frac{1}{2}$ in. wide. The speeds in single gear vary from 92·8 to 560 revolutions per minute, and in double gear from 11·4 to 70. Three feeds are provided, 8, 16, and 32; or 4, 8, and 16 cuts per inch, these being changed by gears in the box at the front of the headstock.

A massive lathe of 28-in. centres by Dean, Smith, & Grace, Ltd., has twenty-four spindle speeds with a double-speed countershaft, graded as follows in revolutions per minute, the speeds being, it must be remembered, especially arranged for turning heavy crank shafts:—Single gear: 560, 430·6, 382, 255·4, 203·4, 156·4, 120·7, and 92·8; double gear: 70, 53·6, 41·5, 31·8, 25·8, 19·4, 15, and 11·4. It is a cone lathe with four steps, the smallest being 21 in. diameter, and the largest 34 in., taking a 6-in. belt. The belt changes are doubled with double back gears, two sliding pinions being slid in and out of engagement with wheels on the main spindle by means of a rack and pinion operated by a lever.

Messrs Tangye's, Ltd., make a range of all-gear head high-speed lathes, either belt, or motor driven. In the 16-in. centre head illustrated, Fig. 164, the belt is 6 in. wide running on 24-in. pulleys A, the great width being an advantage unobtainable when belts have to be shifted from step to step. The photo, Fig. 165, Plate XI., shows a single belt pulley stopped and started by means of the countershaft, being an alternative design to the two pulleys illustrated in the sectional drawing. The gears, combined with a two-speed countershaft, give twenty-four speeds, ranging from 2·2 to 200 revs. per minute. The drive may be from motor instead of the countershaft. If from the latter, lathes above 16-in. centres may be provided with four changes at the counter; a speed variation of about 1·3 to 1 throughout the entire range is obtainable. If belt-driven from a motor, the latter has resistances in the shunt winding, and its speed

may be varied about $2\frac{1}{2}$ to 1. The lathe gears give a very wide range. The front bearing of this lathe measures 7 in. diameter, and 10 in. long. The change-wheel shaft runs at twice the speed of the lathe spindle, which permits a belt drive to the feed motion, a safety device which lessens risk of fracture of the gears in the event of a hitch occurring. The feed shaft is carried at the front below the guide screw. The bed is very massive, being 30 in. wide by 18 in. deep. The saddle has a double apron, between which the feed motion gears are carried. The rack pinion has its axis set vertically in order to provide a bearing on each side of the pinion, and to bring the rack closer under the cutting tool. The loose poppet has a spindle $5\frac{1}{4}$ in. diameter.

The illustration of the head in Fig. 164 gives an end view, to the left, and a conventional plan view to the right, in which the spindles are arranged in one plane. The pulleys A are on a rear shaft B, and this shaft carries three sliding pinions, which must move in unison. An intermediate eccentric shaft C carries three fixed wheels keyed to a sleeve, either of which can be engaged in turn with their fellows on shaft B. There is also a pinion D. There are two wheels on a sleeve on the main spindle E, which may be engaged with the middle wheel on shaft C, or with the pinion D on the same shaft, thus doubling the three speeds obtained on the intermediate. Another doubling is obtained by the pinion F. The sleeve is moved by the clutch and lever seen. It may drive the spindle directly, or if the clutch is out of action, the pinion engages with a pinion on a second intermediate shaft, which in turn transmits the motion to the large wheel G on the spindle. The movements of the sleeves are operated by handles at the front of the headstock. This lathe will cut $\frac{7}{8}$ in. deep with a feed of $\frac{1}{16}$ in., at a speed of 50 ft. per minute.

The following relates to a 12-in. centre lathe by the same makers, driven by a two-speed countershaft to a single-belt pulley, the spindle speeds being further varied by gears in the head. There are first two sets of pulleys on the counter, driven from the line shaft at two speeds. Two additional speeds are obtained through gears driving to a second counter, either of which can be clutched into engagement, and drive the pulley which is belted to the lathe at 440, 382, 330, and 287 revs. per minute. Eight changes of speed are obtained at the headstock, making thirty-two in all, ranging from 4 to 330 revs. per minute of the lathe spindle. The pulley, 20 in. diameter, takes a 5-in. belt. The gears are put in and

Fig. 164.—Head of Tangye Lathe.

out by a friction clutch on the belt spindle, and a claw clutch on the main spindle. The arrangements are such that gears cannot be put in until others are disconnected. The spindle has a front bearing of 6 in. diameter by $7\frac{1}{2}$ in. long. The loose poppet has a barrel of $4\frac{1}{4}$ in. diameter. The remarks made in reference to the belt drive to the feed motion and rack in the 16-in. lathe apply to this also.

The high-speed lathes of John Lang & Sons have the fast headstock fitted with stepped cones of large dimensions. In the 13-in. lathe shown, Fig. 166, Plate XI., the steps are $4\frac{1}{2}$ in. wide, the smallest is 20 in. diameter, the largest 30 in. These large cones are possible by bringing their spindle over to the front of the lathe. Compare with the drawing of the head in Fig. 167. Single and treble gearing are used, the last pinion for the latter engaging with teeth around the face plate. The single gears give a ratio of 6 to 1, the treble of 18 to 1. When turning shafting, a roughing cut may be taken at from 50 to 100 feet per minute surface speed; and by merely moving the locking bolt, a finishing speed of from 16 to 30 feet per minute may be obtained without shifting the belt on the cone. The countershaft makes 300 and 200 revolutions per minute. With the first-named, the spindle rates of revolution per minute are :—74·3, 56·9, 43·8, 33·6, 24·8, 10, 14·6, and 11·2. With the second they are :—49·5, 37·9, 29·2, 22·4, 16·5, 12·6, 9·7, and 7·4. The diameter of the front bearing of the headstock is 6 in. The bed is $22\frac{1}{2}$ in. wide on face, and $20\frac{5}{8}$ in. on body. Incidentally, though not related to the high-speed design, there is a special arrangement embodied for cutting coarse-pitched screws and worms. The cone can be geared directly to the leading screw by change wheels, which stresses the change wheels much less than when gearing is done from the spindle. Thus, when equal change wheels are on the cone shaft and leading screw, the pitch of screw being cut would be 3 in., with a leading screw of $\frac{1}{2}$-in. pitch.

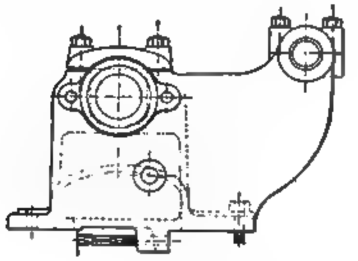


Fig. 167.—13-Inch Centre Lathe. (John Lang & Sons.)

Fig. 168, Plate XI., illustrates a lathe of $10\frac{1}{2}$-in. centres, by Darling & Sellers, Ltd. It is driven by a single pulley, the changes in spindle speeds being effected by gears enclosed in the head. A special feature of the lathes made by the firm is the double-tier bed. The overhang of the saddle is supported by a face or ledge which is parallel with the top face of the bed, but situated lower down. The result

is that the bearing width is increased, and at the same time the guidance is effected by a narrow raised strip on the front part of the front shear; all risk of crossworking is thus eliminated.

In Fig. 169, Plate XI., an interesting example of driving is shown, the lathe being a very massive one of 18-in. centres, taking 10 ft. between centres. The motor, of 60 HP., is mounted at the rear of the headstock, and there are no belts, all the speeds being obtained by gears. A range of cutting speeds up to 400 ft. per minute is obtainable, and feeds from $\frac{1}{16}$ in. to $\frac{1}{2}$ in. There are two rests, at front and back, on the carriage.

The following figures relate to the performances of the lathe exhibited by Sir W. G. Armstrong, Whitworth, & Co., Ltd., at the Liége Exhibition (1905). It was of 18-in. centres and driven with a 60 HP. motor, the material turned was forged steel, using the "A.W." high-speed steel.

Cutting Speed. Feet per Minute.	Reduction in Diameter.	Feed per Revolution.	Weight of Metal removed per Hour.
	In.	In.	Lb.
160	$\frac{3}{8}$	$\frac{1}{16}$	611
100	2	$\frac{1}{8}$	2,545
42	2	$\frac{1}{4}$	2,140
38	1	$\frac{1}{2}$	1,935
32	$2\frac{1}{2}$	$\frac{1}{4}$	2,039

The Loose Poppet.—As the poppets of existing lathes are not strong enough to endure the stresses of heavy high-speed cutting, new designs are being evolved. In the first place the single hold-down bolt generally employed is not strong enough, hence three or four bolts are being used. These are necessarily short, to avoid stretch and spring in service, and this modifies the design of the head. In general it is not possible to make the foot of the poppet span the shears and be clamped to their edges, because that would prevent the movement of the carriage of the rest past the poppet. Tee-head bolts in tee-slots are therefore used commonly. Where the keep is retained the number of bolts is increased to two, three, or four, with special methods of fitting. The bolts are also made to pull washer strips up against the under sides of square edges situated within the shears. In the case of the bed for the 30-in. Hulse lathe, in Fig. 162, Plate X., the headstock spans the inner shears and the strips are pulled against the under part of the same. In the same lathe the end thrust on the poppet spindle is further resisted by a dog engaging with the teeth of a ratchet rack within the bed. A coupling link is fitted in front to be attached to the carriage of the slide rest, which is pulled along the bed by a motor of 10 HP. specially provided for this function alone.

The next point in relation to the loose poppet is that the general build is stiffer, and especially the spindles; the one for the 30-in. lathe mentioned is 7 in. diameter. The friction on centres is enormous. The centres stick, and it becomes difficult to force them out with the hand-wheel and screw.

Power Required.—The stresses in heavy cutting are enormous. Mr Gledhill says that forged steel offers a resistance to cutting of 100 tons per square inch. A tool $1\frac{1}{4}$ in. square took a cut $\frac{7}{8}$ in. deep by $\frac{1}{4}$ in. feed, at a cutting speed of 90 ft. per minute, removing $68\frac{3}{4}$ lb. of metal per minute. Under these conditions, with the tool projecting $1\frac{1}{8}$ in. beyond the rest, the stress on the tool is estimated to be 78·5 tons per square inch.

Though the power required to drive high-speed lathes is greatly in excess of that necessary for lathes using tools of carbon steel, yet the first-named are more economical because the frictional losses do not increase in the same proportion. Though more power is required, the increase in power is not in proportion to the extra work done. Thus Mr Gledhill instanced a case where, cutting on hard steel with $\frac{3}{16}$ in. depth of cut, and a cutting speed of 17 ft. per minute, 5·16 HP. was absorbed. Increasing the cutting speed to 42 ft. per minute, retaining the same depth of cut and feed, there was a saving of 19 per cent. in power for the work done. In another case, with a depth of cut of $\frac{3}{8}$ in. and traverse of $\frac{1}{16}$ in., compared with $\frac{3}{16}$ in. depth of cut, and $\frac{1}{16}$ in. traverse, showed a saving in power of 28 per cent. Dr Nicolson has shown that about the same weight of metal can be removed per minute by

a horse power, irrespective of speeds, within reason.

High-Speed Tool Steels.—These were introduced by the Bethlehem Steel Co. and shown in operation first at Paris, at the Vincennes section of the Exhibition (1900). A lathe of about 30-in. centres cut mild steel of 0·2 per cent. carbon at what was then the unprecedented rate of 145 ft. per minute. The depth of cut being $\frac{3}{16}$ in., the feed $\frac{1}{16}$ in., 5·8 lb. of cuttings were removed per minute, the tools enduring twenty minutes. That rate of performance is now much increased. English firms went into the matter of high-speed steels, as also of the lathes to utilise them, and the success achieved has been marvellous. There are now several brands in regular use, and well known, by different firms.

A peculiarity of the high-speed tool steels is that they are not hardened in water, but in air, either in still air, or in a blast, the latter being preferable, hence the term *air-hardening* steels. This is explained by the fact that carbon does not play any important part in these steels. The essential elements are chromium, tungsten, molybdenum. Manganese is of less importance. The proportions of the above-named elements vary in different samples, and a vast amount of experimenting has been done with these differently proportioned, bearing on the chemical composition, and also on the best methods of hardening.

The Armstrong-Whitworth Company have experimented to find the influence of the elements in the high-speed steels. Some of the principal results are here summarised.

Carbon.—By hardening in a strong air blast, it was found that the greatest cutting efficiency is obtained when the carbon ranges from 0·4 to 0·9 per cent. The steel is much tougher than when higher percentages of carbon are used, when the tools are liable to break.

Chromium.—Steels containing a low percentage of this element are very tough, and suitable for cutting the softer qualities of steel and cast iron. But for harder materials the chromium has to be increased. But then the content of carbon must be diminished. It was also found that chromium is as valuable as the more costly vanadium.

Tungsten. — Experiments in which the tungsten ranged from 9·0 to 27·0 per cent. showed that up to 16·0 per cent. the steel became very brittle, though its cutting capacity was good. Between 18 and 27 per cent. the steel became softer and tougher, but while cutting cleanly, would not stand so well.

Molybdenum.—The peculiarity of molybdenum steels is that they do not require so high a temperature for hardening as the tungsten steels. It should not exceed 1,800° Fahr. But a lesser percentage of molybdenum than of tungsten will suffice to make a good high-speed steel.

Silicon.—Silicon hardens high-speed steels, and the cutting efficiency is increased by additions up to 3 per cent. Over that the efficiency begins to decline.

One of the best qualities of "A.W." steel gives carbon, 0·55 per cent.; chromium, 3·5 per cent.; tungsten, 13·5 per cent.

Forging.—The rapid steels are forged at a yellow heat, about 1,850° Fahr. When it drops to about 1,500° they should be reheated. The heating must be thorough, or cracking may result.

Hardening.—This is done at a white heat verging on melting. The tool is then hardened in an air blast. Some tools are cooled in oil when a sharp edge is required, as in finishing tools. Then they are ground on a dry stone, followed by heating to a white heat, cooled down in air blast to a bright red, and then quenched in a bath of rape, or whale oil, or a mixture of both.

The obvious peculiarity of the rapid steels is the high temperature which they endure, in marked contrast to the carbon steels. Tools of the latter begin to lose their hardness as friction raises the temperature to about 500° Fahr., the *critical* temperature. Hence the reason why the temperature should be kept below this, which limits the speed of cutting. But with the high-speed steels the critical temperature extends to 1,100° Fahr., or 1,200° Fahr. Also the higher the temperature for hardening is raised above the critical point, and rapidly cooled, the higher will be the temperature which the tool will stand in service. The intensity of hardness is increased by rapid cooling, hence the value of the air blast. But

the very rapid quenching required for carbon steels is not necessary.

These steels are forged, reforged, and hardened at a welding heat, which would ruin carbon steels. The temperature is from 2,200° to 2,300° Fahr. Fusion of the cutting edge takes place, and then the tool is cooled. Unless this temperature is reached the tools will not be efficient. No quite satisfactory explanation has been offered of the behaviour of these steels. Probably the best is that at the temperature of practical fusion, the elements just now named combine with the carbon, forming crystals of extremely hard carbides, which remain embedded in the softer steel of the tool body. These endure the high temperature at which cutting is done, while the softer matrix becomes abraded. At the high temperatures induced by cutting, the turnings become blue and smoke, and at such temperatures the steels prove most efficient. The stress on the tool point is so severe that the top of the tool becomes abraded, and the top rake is altered until it becomes right at an angle of least resistance.

Speeds of between 300 and 400 ft. per minute are practicable. But it is found that the most efficient work is done at much lower speeds, not only for roughing, but for finishing. Broadly, working limits lie between about 50 and 100 ft. surface speed for roughing and finishing respectively on the mild steels. These permit of coarse cuts and feeds, and here the high-speed steel tools are seen to most advantage. 15 or 16 lb. of turnings removed per minute are common, and these amounts are doubled and trebled in some instances.

Mr Gledhill has given an instance of what may be termed the indirect saving derived from the use of high-speed steels: that of avoiding the cost of forgings by turning down from the rough bar, a feature which is paralleled in work done in heavy turret lathes. The example was that of armour-plate bolts. When forgings were made, and turned with self-hardening steel, eight bolts per day of ten hours was the output. By using rapid cutting steel, and turning the bolts from plain rolled bar, forty bolts were produced, an advantage of five to one, in addition to the saving in the cost of forging. In fact the cost of forging one bolt alone amounted to more than the cost of machining twelve such bolts. They were turned at the rate of 160 ft. per minute, with $\frac{3}{4}$ in. depth of cut, and $\frac{1}{32}$ in. feed. The weight of metal removed from each bolt was 62 lb., or 2,480 lb. in a day of ten hours, the tool being ground only once during that period.

The high-speed steels do not make so good show on cast iron as on mild steel. But much better results are obtained now than formerly. Mr Gledhill mentions the case of some piston blocks for air compressors, 20 in. diam. by 5 in. wide, turned at a cutting speed of 150 ft. per minute, $\frac{3}{16}$ in. depth of cut, and $\frac{1}{32}$ in. feed, five of which were turned with an A.W. tool without injury to the latter. Also a winding drum for an elevator was turned at a speed of 102 ft. per minute, with an $\frac{1}{8}$ in. to $\frac{3}{16}$ in. cut, and $\frac{3}{32}$ in. feed.

Formerly it was believed that fine finishing cuts could not be taken with the rapid steels. But though a finer finish is obtainable with carbon steels, yet special cases apart, the finish imparted is suitable for a large volume of shop work. There is also the advantage that the steel being more enduring, it ensures accuracy over a long period, and saves frequent regrinding, so that it is of value for lengthy operations, and for turret work.

Firth's "Speedicut" high-speed steel is forged at a good red or a yellow heat. It is then heated to a white heat, removed to the anvil and hammered all over the nose (in the case of a lathe or planer tool) until a bright red is reached, and then cooled in a blast of air. The hammering is found to improve results. Certain tools may be plunged at a white heat into oil; the makers also recommend in the case of delicate tools that they should be boiled for an hour or so in the oil (after first being allowed to get cold after hardening), in order to relieve internal strains caused by the hardening. The firm also find that the usual quality of high-speed steel, though satisfactory for ordinary classes of work, does not stand up so well on hard steel, old tyres, &c., and have consequently introduced a slightly different kind for this particular service. "Speedicut" twist-drills show good results; average practice for instance with a 1-in. drill shows that on mild steel it may

Fig. 163.—High-speed Lathe at Work. (Dean, Smith, & Grace, Ltd.)

Fig. 165.—16-Inch Tangye High-speed Lathe, with All-Gear Head.

Fig. 166.—13-Inch High-speed Lathe. (John Lang & Sons.)

Fig. 168.—10½-Inch High-speed Lathe, with All-Gear Head. (Darling & Sellers, Ltd.)

Fig. 169.—18-Inch High speed Lathe, with Motor Drive. (Sir W. G. Armstrong, Whitworth, & Co., Ltd.)

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be run at 300 revolutions per minute, with a feed of 5 in. per minute, and on cast iron 200 revolutions, with the same feed. Experimentally, however, a 2-in. drill has been driven up to 5 in. per minute, which pulled up the drilling machine.

The high-speed steel made by Cammell, Laird, & Co., Ltd., was recently the subject of some interesting tests by the inspector of a railway company. A brief extract from the tables prepared is all that we can find space for. The test bars were of ·33 per cent. carbon and of ·545 per cent. carbon. In the first case the tools were ground to an angle of 64°, with 10° of front clearance. Out of eighteen trials, with a cut of $\frac{5}{16}$ in., traverse of $\frac{1}{16}$ in., and speeds ranging from 65 to 70 ft. per minute, and duration of test of from twenty-seven to thirty minutes, only three cases were recorded of the tools being worn slightly. In one instance, after working at 70 ft. for thirty minutes, the tool being *red hot* for twelve minutes of the time, it was marked as in good condition. With the ·545 per cent. carbon bar, on which a cut of $\frac{5}{16}$ in., traverse of $\frac{1}{16}$ in., speed of 55 to 60 ft. per minute, and cutting period of twenty minutes were taken, the tool was entered as "very good" in seven cases, "good" in ten, and "slightly worn" in one case. The angles in this case were 73° cutting, and 11° clearance.

"Novo" high-speed steel, manufactured by Jonas & Colver, Ltd., is forged at a yellow or nearly white heat, and is hardened at a bright yellow, almost white, in an air blast. Certain tools of rather delicate nature, such as milling cutters, taps, reamers, drills, &c., may be hardened in oil, in order to prevent the formation of heavy scale on the cutting edges. Punches are treated specially; they are first brought to a red in the furnace, then to a white heat in white-hot lead in a crucible, the air being excluded, quenching being done in oil. Scaling is thus obviated. The punch is then drawn to a blue, this temper being found the most satisfactory. It is important in the case of other tools, such as milling cutters, to exclude air during the heating, by employing a closed furnace, otherwise heavy scale is produced.

Milling and other Cutters.—As the cutting edges of these must not be fused, a special muffle furnace is employed, heated by gas, or oil, and having a shelf dividing it into two chambers, kept at different temperatures. The cutters are placed on top of the furnace, to be warmed through, then removed to the upper chamber and heated to about 1,500° Fahr., and then to the lower chamber to about 2,200° Fahr. The cutter is then revolved in front of an air blast, until the tool can be just handled, and then plunged into a bath of tallow of about 200° Fahr. The temperature of the bath is then raised to about 520° Fahr., at which the cutter is plunged into cold oil. Electricity is also used for heating and tempering.

Milling cutters of high-speed A.W. steel, operating on rolled bars, produce ninety hexagon nuts for $3\frac{3}{8}$-in. bolts per day, against thirty formerly produced by cutters of ordinary steel. The cutting speed is 150 ft. per minute, the maximum depth of cut is $\frac{5}{8}$ in., the width 7 in., and 675 lb. of metal are removed in a day. The cutters are 8 in. diam., and usually mill 300 nuts without regrinding.

The Armstrong-Whitworth plano-miller at the Liége Exhibition driven by a 40 HP. motor gave the following records, using A.W. high-speed steel:—

Size of Cutter.	Material Cut.	Cutting Speed.	Metal Under Cut.		Travel per Min.	Weight of Metal removed per Hour.
			Depth.	Width		
		Ft. per Min.	in	in.	in.	lb.
6 in. diam. by 12 in. long -	Forged steel	192	$\frac{1}{8}$	$7\frac{1}{2}$	8	127
6 in. diam. by 12 in. long -	Forged steel	180	$\frac{1}{2}$	$7\frac{1}{2}$	6	382
6 in. diam. by 12 in. long -	Forged steel	75	$1\frac{1}{4}$	$7\frac{1}{2}$	1·2	191
5 in. diam. - - -	Cast iron -	107	$\frac{3}{4}$	6	4	305

Large numbers of twist drills of high-speed steel are in use. Good examples are: drilling mild steel $2\frac{1}{2}$ in. thick, composed of five $\frac{3}{8}$-in. plates, and one $\frac{5}{8}$-in. angle, A.W. twist drill, $\frac{15}{16}$ in. diam., running at 275 revs. per min., feed of 75 cuts per in. of penetration, 7,924 holes were drilled without regrinding the drill, each hole occupying forty-two seconds. Other instances are shown in the Table:—

Diam. of Drill, A.W. Steel.	Material Drilled.	Speed. Revs. of Drill per Minute.	Speed. Cutting Speed, Feet per Minute.	Feed. Cuts per Inch of Traverse.	Feed. Feed, Inches per Minute.	Number of Holes Drilled.	Condition of Drill.
in.							
1	Two $\frac{7}{8}$-in. plates secured together	497	130·1	46	10·8	50	Good
$\frac{3}{4}$	”	497	97·6	46	10·8	50	”
$\frac{5}{8}$	”	497	81·3	46	10·8	50	”
$\frac{1}{2}$	”	497	65·0	46	10·8	50	”
$\frac{3}{8}$	”	497	48·8	46	10·8	50	”
$\frac{1}{4}$	”	497	32·5	46	10·8	28	End of drill broke
$\frac{25}{32}$	2-in. cast-iron plate	630	129·0	35	18	400	Good

Other drilling records are: A $\frac{3}{4}$-in. drill, working on cast iron with scale on, 4 in. thick, revs. 360 per minute, drilled 137 holes before regrinding. A.W. twist drill, $\frac{3}{4}$ in. diameter, 525 revs. per minute, drilled through a 4-in. block in eighteen seconds, equal to 13·2 inches travel per minute.

The following comparison between the work of drills made of ordinary carbon steel, and high-speed steel (0172 Cammell-Laird steel) shows the economy of the higher priced article. A $\frac{3}{4}$-in. drill of ordinary steel, running at 32 ft. per minute, drilled 36 holes in forty minutes through a plate of high carbon steel $1\frac{1}{4}$ in. thick, after which the drill required to be ground. A $\frac{3}{4}$-in. drill of 0172 high-speed steel run on the same machine at 60 ft. per minute, drilled 150 holes in eighty minutes through a similar plate, after which it was reground. The results as regards cost spread over a large number of holes are summarised:—

Result.—For 15,000 holes. Ordinary steel drills; five drills at 2s. 7d. each, 12s. 11d.; labour, at $6\frac{3}{4}$d. for 36 holes, £11. 14s. $4\frac{1}{2}$d.—Total, £12. 7s. $3\frac{1}{2}$d. "0172" steel drill; one drill at 5s. 7d.; labour, at 1s. $0\frac{3}{4}$d. for 150 holes, £5. 6s. 3d.—Total, £5. 11s. 10d. Amount saved by the use of the "0172" drill, £6. 15s. $5\frac{1}{2}$d. In other words, the "0172" drill cost 3s. more in the first instance, and saved that extra cost forty-five times over. Further, with the high-speed drill, the work occupied 141 hours—about $2\frac{2}{3}$ weeks. With ordinary steel drills it occupied 312 hours, or nearly six weeks.

An example of planing work is: planing bed plates; speed 40 ft. per minute, $\frac{1}{8}$-in. traverse, $\frac{1}{16}$-in. depth of cut.

Hipped Roof.—A roof in which ends and sides slope similarly, thus differing from a gable roof, in which the end walls are built up to the apex, and the slope is at the sides only.

In hipped roofs, hip rafters are employed, extending from the ridge plate to the corners of the building, to form the ridges where roof surfaces meet. It is necessary also to fit short rafters, called jack rafters, between the hip rafters, and the wall plates, as shown in the illustration, Fig. 170. The carpenter's work in a hipped roof, therefore, is more complicated than in a gable roof.

To prevent the hip rafters from exerting outward thrust on the corners of the building, an angle brace is bridged across the corners in small buildings, and in large ones the hip rafters are tied by trusses. These latter usually take the form of half trusses, meeting beneath the end of the ridge plate, at the centre of the last complete truss which spans the building. The wall plates, of course, extend completely

round on the tops of the walls, and are half lapped together at the corners. When an angle brace is employed instead of a truss, it is necessary to tusk tenon a short diagonal extension called a dragon beam, from its centre to the extreme corner, and into the end of this, immediately over the wall plates, the end of the hip rafter is notched and stub tenoned, in the same way as a rafter into the tie-beam of an ordinary truss. The outward thrust of the rafter is thus on the dragon beam, which is held by the angle brace attached to the walls at some distance back from the extreme corner. Hip rafters are of stouter section than common rafters. A valley rafter, as shown in the illustration, is the reverse of a hip rafter.

Hip Rafter.—*See* **Hipped Roof.**

H-Iron, or H-Sections.—*See* **Joists.**

Hissing of Arc Lamps.—Caused by boiling or bubbling of the incandescent carbon in the crater formed at the point of the positive carbon, in an arc lamp fed by continuous current. As the carbon points are brought closer together, the current in the arc increases and therefore the temperature of the crater rises, so that the hissing noise is most noticeable when the carbons are striking or feeding forward.

In alternating current arc lamps there is a continuous humming sound produced but this is a magnetic or hysteretic effect due to the rapid reversals of the current.

Hob.—A master tap, or one over which screwing dies are cut. Also a short master or guide screw, or *leader* in a chasing lathe, which controls the traverse of the chasing, or comb tool. A worm tool, backed off and sharpened to produce cutting edges, is also a hob; it is used to cut worm wheels, spiral wheels, and latterly spur wheels. *See* **Hobbing.**

Hobbing.—Cutting the teeth of gear wheels by a master thread or hob. For cutting worm wheels the hob is exactly like the worm that is to gear with the wheel, but fluted and backed-off to form cutting edges. For cutting spur gears the worm shape is retained, but the axis of the hob is set at an angle corresponding with the angle of the worm thread. For cutting spiral gears it is set at this angle, plus the angle of the spiral. See the articles dealing with the cutting of spiral, spur, and worm gears.

Hogging.—The upward curving of the furnace flues of horizontal boilers, due to expansion shortly after the lighting of the fire.

Fig. 170.—Hipped Roof.

Hoisting Engines.—A class of hoisting machines which from small and simple designs has attained great developments. The term *steam hoist* is sometimes applied, but that only denotes one particular design; for these hoists are also actuated by gas and oil engines, electric motors, compressed air, or by belt from an independent source of power.

The simplest type of hoisting engine is one in which a single engine, or double engine, drives a hoisting drum. This is used for all manner of functions about yards, and works; in lifting and hauling, warping, lifting skips, and in driving machinery. Given the drum, and chain or rope; guidance, and transmission are easily accomplished. Speeds vary in single, and geared hoists, and powers range from 4 HP. to 200 HP. The hoists are fixed or portable, self-contained with boiler and engine on one base, or the boiler, or other source of power is elsewhere.

In the majority of hoisting engines the drum is single, in many it is duplicated. In many American designs there are from four to six drums. In many again drums are absent, their place being taken with warping cones, or spools. In others there are drums and cones, one of each on the same shaft. Around these lie the principal variations in this type of hoisting

machine. Many of these variations occur chiefly in the United States, and are called for by the application of the hoist to the operation of derricks in tall erections, as bridges, and buildings. Thus, one drum will be dealing with the load, another derricking, or slewing the jib. Or in bridge erection, each drum or spool will be engaged lifting and setting its own load, whether girder, bar, truss, or beam. Or they can be used for rapid loading and unloading on wharves. Each is independent of the others, but the operating levers are brought to one spot, to be manipulated by one attendant. However drums or spools are arranged, the ropes from one do not foul the others, but pass over, or under one another.

Drums are usually made fast on their shafts in the common hoisting engines, but in the types just instanced they are generally loose, and put into action by friction cones, with great advantage, while the engines are in motion. Where there is more than one drum, each has its own independent friction. The usual method is to slide the drum endwise on its shaft to engage with a wooden friction ring having the sectional form of a frustum of a cone, to fit in an annular recess in a flange on the drum. Frictions of leather are also used. In some English types, grooved friction gearing is used to drive and disconnect.

Band brakes are generally used to supplement the friction of wood blocks and so lessen their wear. These loose drums are used in pile driving, so that the monkey in its descent is not detached from the rope, but overhauls the rope in the loose drum, and then the monkey is drawn up by throwing the clutch in.

There is a limit to the length of rope that can be wound on a drum, though some drums will wind as much as 1,600 feet on a single lap, and speeds as high as 1,000 feet a minute are obtained. It is better not to wind more than one coil of rope on a drum, and here the value of the warping cones or spools comes in. Only the lap of rope in actual service is being wound, and the rest is coiled up behind the spool. There is thus no limit to the length which can be warped in. Drums and spools should be turned and balanced for high speeds, and it is better as a rule to groove the drums.

Fig. 171, Plate XII., represents a type of hoisting engine used in conjunction with an elevator, for lifting hods, &c., to the different stages of a building under construction. It has double cylinders of 5-in. bore, and is fitted with link reversing gear. The drum, of 14-in. diameter, is loose on the shaft, and is provided with a wood cone friction, which is thrown in, and locked if necessary by a handle working on a quadrant. A differential band brake is provided for the drum, or the ratchet and pawl may be thrown into action should the load remain on for a considerable while. The wheel seen on the end of the drum shaft has a concave rim, and is used for operating the ropes for the elevator cages, several turns being taken to secure sufficient friction. This wheel is thrown into operation by a clutch. By mounting the boiler on the bedplate, a compact arrangement is secured, and the weight obviates the necessity for bolting down.

A double barrel type of hoisting engine is illustrated in Fig. 172, Plate XII. It is placed separately from the boiler. The use of two drums enables a couple of derricks to be operated, or a single derrick may have its lifting rope run by one drum, and its derricking by the other. The engine is also of service for pile driving, and various haulage work. The friction cones used for coupling up the drums to the shafts comprise a ring of wood sectors engaging with coned internal surfaces. Band brakes and ratchet wheels are fitted. Winch heads for warping are placed on the ends of the shafts. A view looking down upon a similar class of engine is given in Fig. 173, Plate XII.

Another double-drum pattern, Fig. 174, Plate XII., has a special reversing drum (seen to the right), which is geared internally to rotate slower than the main drums. It is used for operating a rope passing around the bull wheel of a derrick mast, to slew the crane. *See also* **Haulage Gears**.

Hoists.—Goods lifts, or similar appliances. Hoists are used in warehouses and railway goods sheds, on board ship—for ammunition and for ashes, in flour mills, and also for cupolas, blast furnaces, general factories, and building operations. They usually take the form of a platform—with or without sides

PLATE XII.

Fig. 171.—Single Barrel Hoisting Engine.
(Lidgerwood Manufacturing Co.)

Fig. 172.—Double Barrel Hoisting Engine.
(S. Flory Manufacturing Co.)

Fig. 173.—Double Barrel Hoisting Engine.

Fig. 174.—Double Barrel Hoisting Engine, with Special Winch Head.

(Rawson & Morrison Manufacturing Co.)

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—guided to ascend and descend a shaft or between guide posts. This vertical movement distinguishes the hoist from the jib cranes, and the travellers. But the term hoist is often used as synonymous with lift, and winch, and with the forms of direct-lifting air hoists that are travelled on runways. Methods of operation include hand, steam, water, air, and electricity, described under suitable headings.

An example of an ammunition hoist for supplying big guns on board ship is given in Fig. 175. It was made at the Elswick works of Messrs Sir W. G. Armstrong, Whitworth, & Co., Ltd.; it is a dredger hoist employed for 6-in. projectiles and charges. A continuously running chain carries buckets, and a table is provided at the bottom, on which the projectiles and charges are placed alternately so as to come in the path of the buckets. The latter have clips which are open, but automatically embrace the projectile or cartridge, till these reach the top, when they are made to release while the load is passing the top sprocket wheel. The projectiles or cartridges are received in a special trough or table at the top, which is so arranged that they do not fall on top of one another. This hoist is capable of supplying about twenty-four items of ammunition per minute. It is shown on the drawing as worked by an electric motor, but of course a hydraulic motor can be used.

In another type, designed to supply ammunition to a 12-in. gun, the aim is to transfer the shot and cordite from the floor of the chamber below the gun turntable to the rear of the gun. The problem is complicated by the fact that it

Fig. 175.—Ammunition Hoist. (Sir W. G. Armstrong, Whitworth, & Co., Ltd.)

is necessary to stop the ammunition cage in line with the gun (and the rammer which is attached to the gun slide), wherever the gun may be in elevation or depression; also that the gun may have its elevation altered during the time the cage is discharging into it. Moreover, when the cage is on the chamber floor loading up, it is not to be disturbed by alteration of the gun elevation. The cage runs on curved guide rails, the radius of which is struck from the trunnion centre on which the gun is pivoted. A hydraulic cylinder below the gun actuates the wire rope by which the cage is hoisted. The compensating gear, by which the cage is kept in line with the gun, is actuated by pulleys connected to the hydraulic cylinder and ram which elevate or depress the gun. Pulleys on these slightly alter the position of the cage hoisting rope, and cause the cage to follow the motions of the gun automatically.

In an example where two 10-in. guns have to be supplied there are two carriages running on guides up to the sides of each gun. These are actuated by a cylinder provided with rack teeth working into a pinion rotating a rope drum; hand gear may be fitted as a standby. Each cage carries one projectile and two half-charges below it. Three rounds of ammunition are sent up per minute, the lift occupying four seconds. The loading is done from tipping shelves below, which empty the items into the cage shelves; on arriving at the top the shot is passed on to a swinging tray by which it is carried partly into the gun. The powder is tipped out on to the gun-house floor, and carried to the gun by hand.

Holding-up.—Affording resistance to riveting by holding a hammer, the *holding-up hammer*, under the head. It differs from a dolly in being handled, and the leverage of the long handle is made the means of keeping the hammer to its work.

A piece of work is said to *hold up* when there is sufficient material to permit of giving proper finish, as in planing, turning, and other machine operations.

Hole Grinding Machines, or **Bush Grinding Machines.**— These have grown vastly of late years, due to the substitution of grinding as a finishing operation for boring. Their capacity has increased also from that of simple bush grinding to include the bores of cylinders for small engines, and for motors. Allied to these in some respects are the link grinders, which receive separate treatment.

The problem of grinding a hole truly is not so simple as it may appear. There are two cases, that of rotating, and that of fixed work; the first offering no special difficulty, the second requiring a very special piece of mechanism. The origin of hole grinding is to be traced in the lead laps cast round an iron mandrel, run between lathe centres, and charged with emery powder; a device that remains in use, though to a great extent displaced by the grinding machines. Another is the fitting of a grinding spindle to the rest of an ordinary lathe, driven

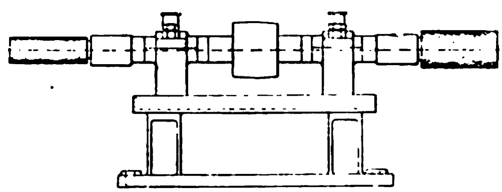


Fig. 176.—Hole Grinder.

by a belt from a long drum on the countershaft. This, however, is not a device to be recommended, because of the damage inflicted on the lathe, which has no special provision for protecting the ways and bearings from the scoring action of the gritty particles.

The simplest machines made specially for hole and bush grinding are those having an emery roller, or two rollers driven by a belt pulley, and bolted down to a bench or standard, Fig. 176. They have no provision for ensuring exact results, the work being held and traversed along the wheels by hand, just as it is moved over an emery lap in the lathe. But these machines are useful for a large volume of comparatively coarse work which would otherwise be rough bored, or not bored at all, or filed, or cleaned out with a flat bit. Pedestal bearings are often ground thus, and the curves of cod pieces or pads, or a rough grinding may be done in order to save the edges of cutting tools later, when the allowance for tooling is rather too fine to allow a cutting tool to get beneath the hard skin.

In precision machines the spindle has very long bearings to ensure steadiness of running at high speeds, and either the spindle or the work is traversed bodily. The radial feed is applied simply by imparting a radial adjustment to the spindle; as the work revolves, as well as the wheel, this radial adjustment is sufficient. An illustration of such a spindle is given in the article **Grinding Machines**.

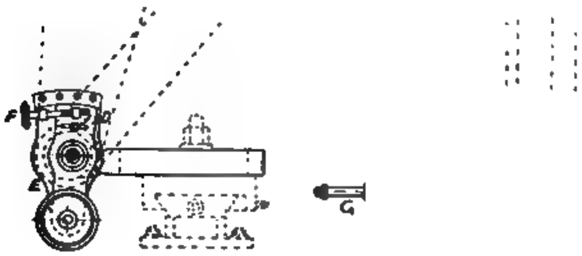


Fig. 177.—Planet Spindle.

But when work cannot be rotated, as is the case in all large and awkwardly shaped articles, then the rotation of a grinding spindle on its own axis, and radial feed is obviously insufficient. There must be in addition to the rotation of the grinding wheel on its axis, that of the axis itself in a circle, the radius of which will also be capable of variation, termed a *planet motion*. All grinding spindles for stationary work must have this motion, but the methods of imparting it vary. A method of obtaining this is illustrated in Fig. 177, by the London Emery Works Co., together with one machine among several to which it is applied in Figs. 178, 179, in which also the countershaft arrangements are seen.

With regard to the essential motions in Fig. 177, A is the pulley, driven by a long drum on a countershaft overhead, and from which the rotation of the grinding spindle B is derived through the pulleys *a*, *b*, *c*, and *d*. At the same time its axis is carried round in a circle by mechanism derived from the pulley C, belted

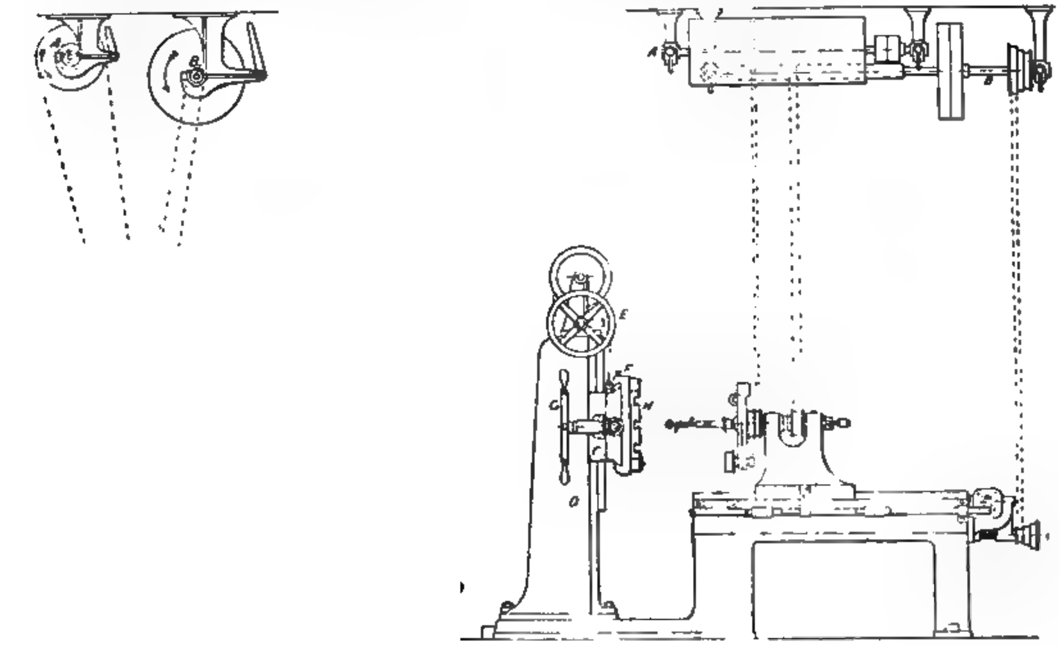


Fig. 178.—End Elevation. Fig. 179.—Front Elevation.
Hole Grinding Machine. (London Emery Works Co.)

from another countershaft. This is effected by the movement of the plate D over the plate E, which plates are pivoted at *e*, and by which the

grinding spindle is set eccentrically—compare with the face view. A vee strip bolted to E maintains the plate in contact. Adjustment between the plates is effected by the screw F, and the plates are clamped by the bolt *f*. The diameter of the hole being ground is twice the eccentricity of the spindle, plus the diameter of the grinding wheel. The rotational speeds are rapid for the grinding wheel on its axis, and slow for the rotation of the axis round the circle.

Figs. 178, 179 illustrate one of the larger hole grinding machines, to which this spindle is fitted. The height to centre of spindle is 43 in., the length of bed 55 in., and it has a slotted face plate, measuring 5 ft. 9 in. × 14 in. It is specially adapted by the gap to receive connecting, and side rods. The two countershafts A, B are driven from the line shaft—not shown—at revolutions of 500, and 30 per minute respectively; the first for the emery wheel spindle, the second for traversing the grinding head, and for operating the planet movement. Each countershaft A and B has its set of fast and loose pulleys, and long drum, to permit of the belt following the traverse of the head. The mechanism of the latter is identical with that just described.

The work is carried and adjusted by the movement of the long slide C on the pillar D, fixed to the base of the machine. The slide is adjusted by the hand-wheel E, which actuates a worm engaging with a wheel on the vertical elevating screw. A cross slide F is traversed along C, by a hand-wheel G, which actuates the screw through mitre gears. F carries the face plate H, which swivels thereon to any angle with clamping bolts, and has tee grooves to hold the work. The weight of the face plate and slides is counterbalanced as shown.

A planet spindle of another design by the firm *Le Progrès Industriel* is shown in Fig. 180. The grinding spindle A runs in a sleeve B. The spindle is driven by the pulley C, and the sleeve by D, E being the loose pulley. The eccentricity is varied by the worm *a*, turned by the milled head F, and engaging with worm teeth *b* cut in the sleeve B. The provisions for lubrication and protection from grit may be noted. Grinding wheels of different sizes are held on the spindle nose.

Fig. 180.—Eccentric Spindle. (Le Progrès Industriel Soc. Anon.)

Fig. 181 illustrates the principle of the spindle by Friedrich Schmaltz, together with its utilities. The spindle A rotates in an eccentric sleeve B, and the latter in a casing C. The mechanism for imparting the eccentricity is varied in different designs of machine by this firm, and the casing C is either belt or gear driven. The result is shown in the figures. In the first figure the spindle is set eccentrically for hole grinding; in the second it is set eccentrically for grinding a pin instead of a hole; in the third figure it is set centrally, and the

work is fed past it, so grinding straight edges.

The device by Mayer & Schmidt differs from either shown. Instead of producing the planet motion by eccentric cylinders, the cylinders have their axes set at different angles. The which a plate E fits. The spindle is supported at the front in a casing. The driving is done from the single spindle F, from the pulley G, driven from the countershaft. Then the pulley H drives the pulley J on the spindle at the high rate of 7,000 revs. per minute, and the pulley

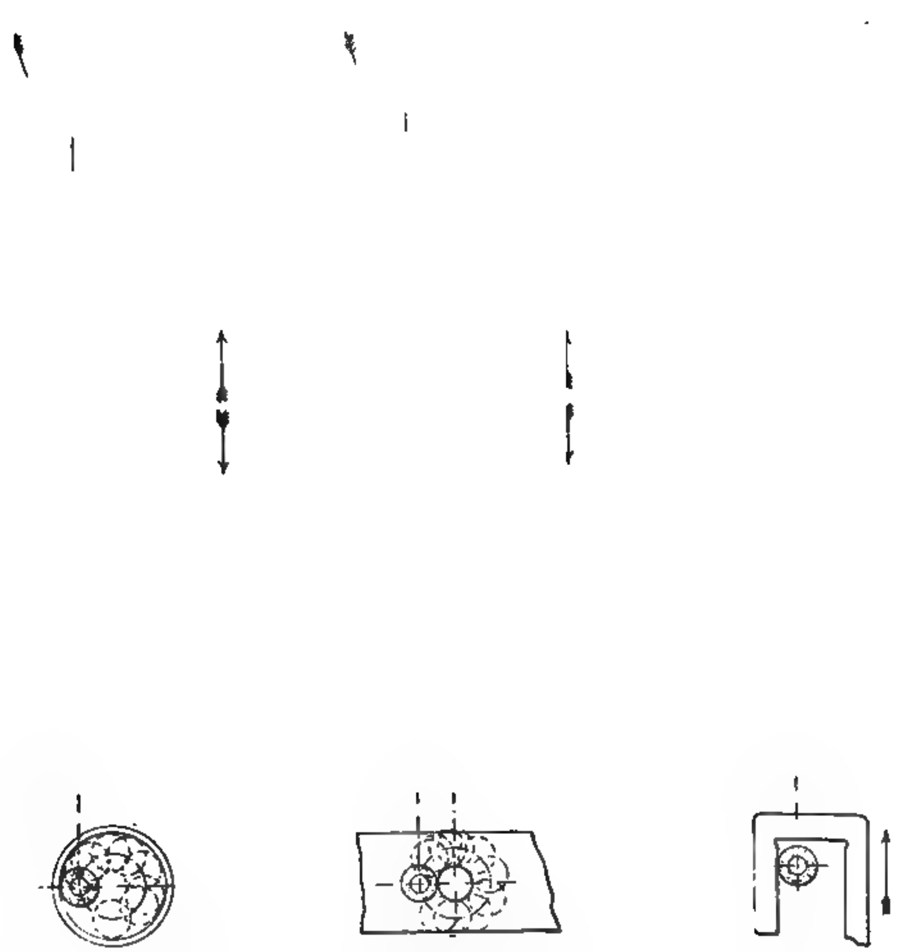


Fig. 181.— Applications of Planet Spindles.

grinding spindle A, Fig. 182, runs in the sleeve B, having its axis set at an angle within the casing C. A hand-wheel D screwed in the boss draws the sleeve C along, and thus regulates the amount of eccentricity of B. B cannot move endwise because it is retained by a groove into K drives the sleeve C through a train of gears, the last of which engages with a ring of teeth on the sleeve. The sleeve makes about 30 revs. per minute. The belt from H to J is tightened by a telescopic adjustment with a set-screw. *See also* **Link Grinding Machines.**

Hollow Blows.—Hammer blows to which there is not sufficient resistance opposed to prevent elasticity.

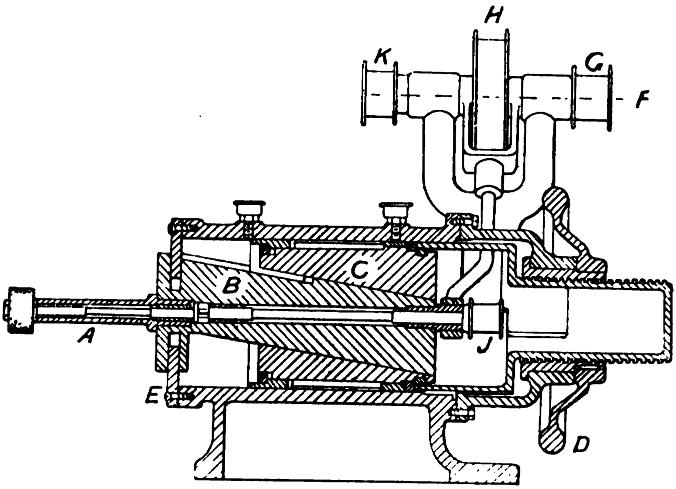


Fig. 182.—Planet Spindle.

Hollow Chisel.—A tool for cutting slots or mortises in timber, consisting of a square chisel, within which is fitted an auger. The end of the latter projects slightly, and so bores a round hole, the four edges of the chisel immediately following, and squaring out the corners. A reciprocating motion is imparted, so that the auger and chisel pass into the wood and out again, while a longitudinal feed provides for mortises of the length desired. The revolutions of the auger withdraw the cuttings, so that choking is not liable to occur.

The machines in which these chisels are used comprise both vertical and horizontal types, embodying provision for clamping the timber, and moving the chisel in its two directions—by hand or treadle in small machines, and by power in large ones.

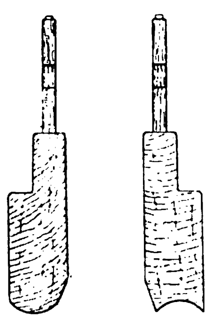


Fig. 183.—Round and Hollow Planes.

Hollows.—*See* **Fillets.**

Hollows and Rounds.—Are narrow planes, Fig. 183, used by joiners, cabinet-makers, and pattern-makers for planing the concave and convex parts of mouldings, or other parts. Their soles are formed either convex, or concave to a definite radius, and the irons ground to suit. In pattern-making, only the planes for hollows are considered necessary, convex parts being produced with ordinary flat-sided planes. In the other trades also it is better to have a large stock of planes for hollows than a small set of pairs.

Hollow Sett.—*See* **Smiths' Tools.**

Hollow Spindle, or **Mandrel.** — The spindles of many lathes and milling machines are made with a hole running right through the centre. The object in the first case is to pass bars of material through, or to operate split chucks; in the second to remove cutters and arbors by a plunger, or to hold these in securely with a screw fitting. The advantage of being able to turn numerous pieces of work from a single long bar renders the use of the hollow spindle essential in capstan and turret lathes, and automatic screw machines, while its adoption is rapidly increasing in ordinary turning lathes of small and medium dimensions. In the finer classes, such as bench and toolroom lathes, a spring chuck is fitted inside the spindle, and worked by a hand-wheel at the back end. Examples of applications of the above are illustrated in these volumes.

Hollow Structures. — *See* **Machine Framings.**

Hollow Work.—The casting of pots and pans. Also work drawn in dies.

Hone.—A hone or oilstone is employed to impart a fine cutting edge to tools after they have been ground. It is used in the form of a rectangular block, and the tool is rubbed to and fro; or if a slip, the latter is moved instead. Hones are usually of natural stone, but manufactured ones are employed also. The best natural stones are the Arkansas, Washita, Charnley Forest, and Turkey. The Arkansas and Washita are both found in the same locality near Hot Springs, in Arkansas, U.S.A. The term "Charnley Forest" is rather a mis-

nomer, but it is always applied to the stones quarried in Charnwood Forest in Leicestershire. The Turkey is of Turkish origin. For wood-working tools the Arkansas and Turkey are rather too fine and slow cutting. Wood-workers in America generally use the Washita, or a soft Arkansas, while in England the Charnley Forest is the most commonly employed. There are a few other natural stones, but none so much used as the four mentioned.

All these stones may be obtained in different grades and degrees of quality. The Arkansas is divided into two grades, hard and soft. The hard has the appearance of marble, but is much harder, and cannot be scratched by steel. It is used for sharpening the most delicate tools and instruments. The Washita is much softer and coarser, and consequently sharpens a tool quickly. The Charnley Forest is fine and hard, cuts slowly, but imparts a keen edge, and wears very slowly. It is difficult to obtain Turkey stones that are homogeneous in character throughout, and the consequence is they generally wear unevenly. They also crack very easily.

The artificial stones, which are composed of emery, corundum, carborundum, &c., are manufactured in a number of grades, and are perfectly homogeneous. The fact that the grade can be varied to suit any requirements is an advantage which cannot always be obtained with certainty in natural stones. Generally where much sharpening has to be done, it is desirable to have at least two stones of different grades, one coarse and one fine.

The principle on which a hone works is similar to that of a grindstone or emery wheel. It is composed of a quantity of hard particles cemented together, which abrade the steel; and to give the best results, the cement should be washed away as the hard particles wear. Otherwise they clog and prevent the hone from cutting, and the tool also becomes heated when there is no lubrication. Oil is used on a hone, because it gives a finer edge to the tool than when water is used. The oil should not be of a kind that will become viscid, and gum the surface of the stone, nor should it be one that will harden the stone. Linseed oil, for instance, is most unsuitable. Generally in workshops the ordinary engine oil used for lubrication is employed, but neats' foot, or sweet oil is better. The surface of the hone should be kept in good condition by wiping old and dirty oil from it, and applying fresh. It should also be kept flat by rubbing down with emery powder, or sharp sand on a flat hard surface, or passing it over a sheet of emery cloth or glass paper laid on a flat support, or holding it against the side of a grindstone until the high spots are reduced. For convenience in using, oilstones are fitted into a wood block or case provided with a cover.

Tools are sharpened by holding them at a suitable angle, slightly more tilted than the grinding angle, and rubbing them with moderate pressure on the stone till the edge is as keen as the hone will make it. If the rubbing is done entirely on one face of the tool, a burr or "wire edge" is produced on the other side of the edge, and this must be rubbed off at intervals during sharpening. In such tools as ordinary axes and turning chisels the reduction is equal-sided, but in most tools the ground facet is on one side only, and then the burr must be removed with the unground face kept absolutely flat on the stone.

The Ayr stone or Scotch stone is used for polishing marble and copper plate, but also as a whetstone. This variety should always be kept damp, otherwise it will become hard.

Hook.—A firing tool turned down at the end and used for cleaning between fire-bars and clinkering. A hook tool is a cranked tool. For hook wrench *see* **Smiths' Tools**.

Hoop Iron.—Narrow strips of sheet iron used for fastening the corners of packing cases. These range from $\frac{5}{8}$ in. to $2\frac{1}{2}$ in. in width, by from 21 to 12 B.W.G. in thickness.

Hoop Tongs.—*See* **Smiths' Tools.**

Hopper.—A box with sloping sides which receives loose materials, and discharges them into barges, machines, or furnaces.

Horizontal.—Horizontal boilers are those the axes of which are set horizontally. They include Cornish, Galloway, Lancashire, locomotive, Scotch. A horizontal crane is a steam crane having the cylinders set horizontally, and the cheeks low down. A horizontal lathe has its face in that position, though the term Boring Mill is more usually applied. A horizontal milling machine has its spindle set thus, but the term is hardly specific enough to denote any particular design.

Horizontal Boring Machines.—The horizontal position is the most convenient one which can be adopted for long bars which have to pass through work and be supported at the other end. The number of machines using this arrangement is therefore large, and numerous variations are introduced for special purposes. Two main differences are noticeable: in one design the position of the bar is fixed and the work has to be moved vertically and laterally to suit it; in the other the bar is adjustable, and is shifted about to accommodate the work, which is bolted in one position, the two types being used for smaller and larger work respectively. In most cases the work is not moved during boring, but either the bar is fed along, or a head upon it slides.

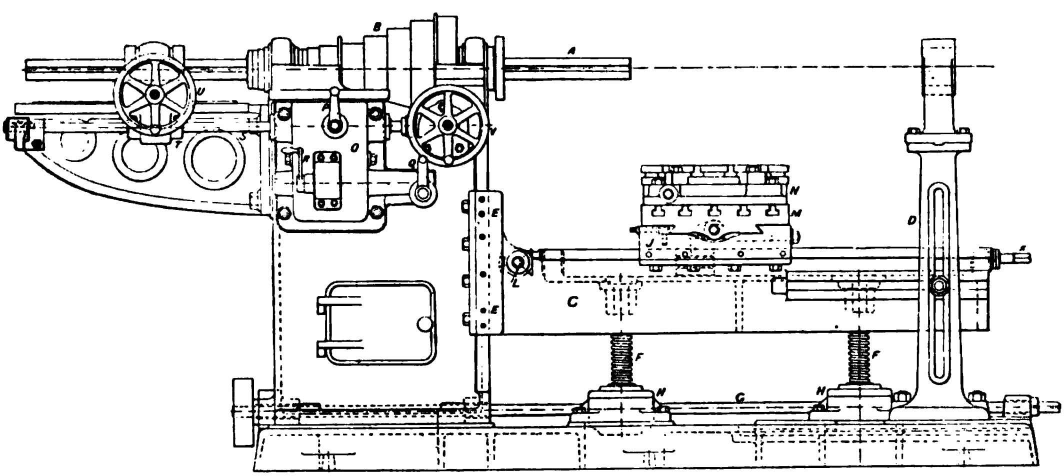


Fig. 184.—Horizontal Boring Machine. Front Elevation. (H. W. Ward & Co.)

Machines are constructed with a single bar, or two or more, to bore separate pieces of work, or several holes in the same casting. Double cylinders may be bored simultaneously, or the four valve chambers of a Corliss cylinder, or the guides and crankshaft bearings of an engine, the bars lying at right angles to each other in the last-named case.

An example of a machine of the first type mentioned above—having an adjustable table—is shown in Figs. 184, 185. The design is one which suggests the lathe in outline, and in fact it has been gradually evolved from that tool, the rising table, and sliding bar introducing points of difference that are necessary for the class of work. The bar A, $2\frac{1}{2}$ in. diameter, is driven from the stepped cones B, back geared (the gears being protected with guards) through keys in splines running the length of A. Sixteen speeds are obtainable in connection with a two-speed counter. Leaving the feed arrangements of the bar for the moment, and considering the table C; this slides on a vertical face of the headstock framing by gibs, and is also clamped by a couple of bolts to a steady D, with vertical slots, and a bearing at the top to receive a bush in which the bar A is steadied. A pair of bolts E, E clamp C at the slide end. Raising or lowering is done by the screws F, F, operated by worm gear from the shaft G, slowly by a ratchet on the squared end at the right, or quickly by power from a belt pulley at the left-hand end. The screws F pass through the worm wheel nuts in bearings H, H. The first slide J moving along the table C, is operated with a screw, rotated at either end as convenient, by the square K, acting direct, or L, working bevel gears. On J there is a cross slide M, provided with tee slots, and above this may be bolted a circular table N, shown in Fig. 184 only.

Returning again to the boring bar; the feeds, of which there are eight, are derived from gears driven from the tail end of the spindle inside the headstock. A set of change-speed gears in the box O, operated by the levers P and Q, and reversed by R, give the eight speeds to the shaft S. The latter has a keyway cut along its length, and drives a sliding worm in the box T.

Fig. 186.—Horizontal Snout Boring Machine, with Circular Holders

Fig. 187.—Duplex-spindle Boring Machine. (Wm. Muir & Co., Ltd.)

To face page 198.

The worm rotates a worm wheel which is clutched to a pinion gearing in a rack in the tail bracket, so that the feed bracket behind T travels along the ways of the tail bracket. The boring bar is moved at will by tightening a couple of set-screws, which press keys into two splines on its sides, and so force the bar to move with the bracket. A quick return may be given to the bracket by the hand-wheel U, and a slow one by V.

What is termed the "snout" boring machine, Fig. 186, Plate XIII., is a favourite type for cylinder boring, especially where one end of the

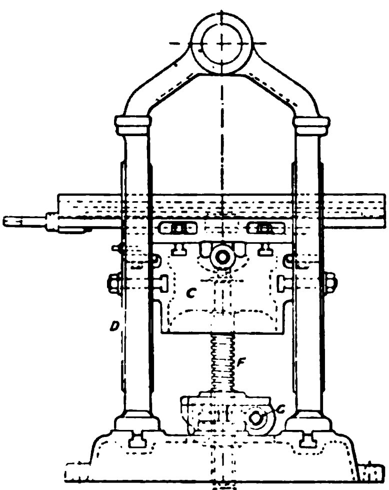


Fig. 185.—Horizontal Boring Machine. End Elevation.

cylinder is closed, as in many steam and gas engines. The boring bar is carried in the head, and passes through the long boss or snout, running in a conical bearing at the end. This snout is stiff enough to support the bar rigidly, so that it may pass into deep bores. A four-stepped cone pulley at the back drives by worm gear to the spindle, and there are four power feeds of the saddle along the bed, and a rapid means of adjustment by the star handle seen in front. For certain classes of work the boring rings shown on the saddle are of service. The cutters are held in the head by a circular plate, and a couple of set-screws to each. Double-spindle machines of the type in Fig. 187, Plate XIII., are used for boring duplex cylinders, pumps, &c.

For objects of awkward shapes, and of large dimensions, the style of machine shown in Fig. 188, Plate XIV., is employed, the illustration representing a comparatively small size. In the larger machines, Fig. 189, Plate XIV., the table and sliding ways give place to a large plain plate, provided with tee slots, enabling the work to be bolted anywhere, and the steady rest (if used) for the bar to be brought up as close as desired. In the machine illustrated in Fig. 188, the bar, provided with a range of speeds, and of feeds, is adjustable on the vertical face of the housing, the tail bearing in the steady frame being adjustable also. The table is moved by hand, or power, and its top swivels, so that holes may be bored at various angles in a piece of work without re-adjusting and bolting it down. Milling can also be done with the spindle, this class of machine often thereby finishing a piece of work outright where it would otherwise have to be sent to a separate miller or planer.

Horizontal Drilling Machines.—These are rather limited in design, the most common pattern being that of a table or base, at one end of which the drilling head is located, being adjustable vertically and laterally. The principal use of the machine is for drilling the holes in pipes and columns, which are too long to be stood on end to have their flanges drilled on a vertical spindle machine. Some rail drilling machines are also made of horizontal type, for convenience of drilling more than one hole at once. Multiple-spindle machines having two heads adjustable along a horizontal bed form a special design for pipe work, both ends being drilled simultaneously, with consequent economy of time. Apart from the above-mentioned machines there is a large class in which boring is accomplished as well as drilling; *see* **Horizontal Boring Machines.**

Hornbeam (*Carpinus*).—A wood used for the cogs of mortise wheels. It is of a light colour, tough and fibrous, and moderately hard. It wears well. Sp. gr. 0·76. A cubic foot weighs about 47 lb.

Horn Block.—The casting in a locomotive framing which receives the axle box.

Horn Plates.—The separate guides which are bolted to truck frames of rolling stock, and between which the axle boxes are placed.

Horse Gear, Bullock Gear, Cattle Gear,

or **Pony Gear.**—A valuable agent where animal power only is available for operating well pumps and other machines. It comprises a long pole to which the animal is yoked, turning the shaft of a crown bevel wheel. This in turn operates a pinion on the end of a two, or three-throw crank, to which the pump rods are attached.

Fig. 190 illustrates a horse gear made by Messrs Hayward, Tyler, & Co., Ltd., for three-throw pumps. The animal is yoked to the *swingle tree* at the end of the pole. The amount of water that can be raised depends on the size of pump, and on the height of lift, for which tables are supplied by the firm. If two horses are used, the same quantity of water can be raised to double the height.

A pony, mule, or bullock cannot do so much work as a horse, and therefore the gear for these are made less powerful than for horses. A bullock also only walks about half as fast as a horse.

Horse Manure.—Used in foundries for mixing with core sand, and loam.

Horse Power.—Proposed by Watt as the measure of power in his steam engines. He doubled the power of a horse, working at a whim-gin. The mean pressure in the cylinders of his engines was 7 lb. per sq. in. He fixed the proper piston speed at $128 \times \sqrt[3]{\text{stroke}} \div 33{,}000$, and called the result the nominal horse power (N.H.P.). As pressures grew, the term fell into partial disuse, though retained for a long time as a standard for selling by, and in marine engines. But engines are now rated by the actual power which they are able to develop, as tested by the indicator, hence termed indicated horse power (I.H.P.). There is no advantage, therefore, in giving the various antiquated rules by which the N.H.P. of various engines might be estimated.

Indicated horse power is obtained from the indicator diagram, from the total area of which the mean pressure in the cylinder is found. This, multiplied by the area of the piston in square inches, and by the speed of the piston in feet per minute, and the result divided by 33,000, gives the I.H.P. of the engine, working only under those conditions of pressure and speed. The I.H.P of a pair of compounded engines is obtained by adding together the mean pressures shown on top and bottom cards, with piston speeds, and areas, and dividing by 33,000. The French horse power, *force-de-cheval*, or *cheval*, equals 75 kilogrammetres of work done per second. The kilogrammetre = 7·233 foot pounds. It is therefore the equivalent of 542·5 foot pounds per second; of 0·99 HP., and of 736 watts. The electrical horse power is 746 watts. *See* p. 201. Since the unit of heat is equal to 772 ft. lb., a HP. $= \frac{33{,}000}{772} = 42{\cdot}75$ heat units per minute.

The horse power of a boiler is an expression for the pressure and volume of steam required to supply an engine of the same horse power. It is a question of grate area, and heating surface;

or in other words of evaporative capacity to produce the steam required. For convenience, makers of boilers often rate them by horse power under given conditions.

A rule often used for Lancashire boilers is:—"Add together the diameter of the boiler shell, and also the diameter of the flue tubes, multiply the product by the length of the boiler; the last product being divided by 6 is the horse power of the boiler. For Galloway boilers 4·5 is usually taken for a divisor instead of 6. The three following rules are usually employed to find the horse power, heating surface, and grate area of Cornish and Lancashire boilers. For horse power, $HP. = \sqrt{S.G.}$ For heating surface, S, $S = \frac{HP.^2}{G}$. For grate surface, G, $G = \frac{HP.^2}{S}$. Roughly, 5 lb. of water are evaporated per square foot of heating surface in Cornish and Lancashire boilers.

Horse Power, Electric.—A rate of electrical working equal to 33,000 ft. lb., the standard of mechanical work. Electrical power is measured in watts (*see* **Kilowatt**), 746 watts being equivalent to one mechanical horse power. The electrical horse power (E.H.P.) of an electric motor is found by measuring the current and pressure of the electricity supplied to it when—

$$\frac{\text{amps.} \times \text{volts}}{746} = \text{E.H.P.}$$

This is termed the "Input" to the motor. Between the E.H.P. input and the "output" or energy given out in the power to turn its shaft against mechanical resistance, there is a loss of power varying according to the amount of load. This loss is plotted in a diagram forming the "Efficiency Curve," from tests of the motor, and by using this curve, the output or "brake horse power" given by the motor to its work can be found.

Then taking the inefficiency percentage of E.H.P. from the total, gives the B.H.P. or value of useful work. Thus, say—

$$\text{E.H.P.} = \frac{32{\cdot}5 \text{ amps.} \times 230 \text{ volts}}{746} = 10.$$

If efficiency at 10 E.H.P. = 86 per cent., then inefficiency = 1·4, and 10 − 1·4 = 8·6 B.H.P. *See* **Electric Motor**.

The power required to operate machinery can be exactly measured by connecting it to an electric motor, either as single units or in groups driven from shafting. The E.H.P. taken by the motor is measured in the same way, and this, *minus* the inefficiency of the motor gives the B.H.P. absorbed by the load.

Thus supposing a motor to be taking 10 ampères, 440 volts, then 10 × 440 = 4,400 watts, and $\frac{4400}{746} = 5{\cdot}89$ E.H.P. input to the motor.

Allowing 88 per cent. efficiency for the motor, gives 12 per cent. inefficiency,

$$\begin{array}{r} 5{\cdot}89 - 12 \text{ per cent.} = 5{\cdot}89 \\ {\cdot}70 \\ \hline 5{\cdot}19 \end{array}$$

5·19 B.H.P. given by the motor for the driving of the machine.

Methods of measuring the efficiency of dynamos and motors are referred to under **Testing—Electric**, &c.

Hose.—Flexible tubing employed for the conveyance of gases and liquids in cases where a rigid connecting medium is impossible or undesirable to employ. The nature of the various gases, such as steam, air, &c., or of liquids, as water, oil, acids, &c., affects the question of material employed in the hose, so that a material suitable for one liquid will be ruined quickly by the passage of another. Rubber is extensively used, alone, or in combination with other materials. Canvas is used to a large extent, notably for fire brigades; and leather, copper riveted down the longitudinal seams, for service where severe usage is anticipated. The methods of protection mentioned under **Armoured Hose** are to a certain extent being displaced by the use of flexible metallic hose, which forms its own protection, the length being made up of spiral metallic rings interlocked with each other in such a manner that flexibility is secured without leakage occurring.

Hot Air Engine.—An engine which utilises the expansive force of heated air. The term *caloric engine*, formerly applied, is a survival of the old belief that heat was a material substance, *caloric*.

Hot air engines should in theory come nearest to the realisation of the ideal engine, air behaving as a perfect gas. In the ideal heat

engine all reduction of temperature during expansion while in the cylinder would be due to the transformation of heat into work. Also increase in temperature would be accomplished while the volume remained constant. In a hot air engine, even an approximation to this ideal would demand cylinders of enormous dimensions, for air is one of the worst conductors of heat. Also the time required would be excessive, and the movements of the engine very slow. Numbers of hot air engines are in use, however, but they are not so economical as gas and oil engines, or even as steam engines. They may be grouped under two heads: those in which the air is heated through a metallic body, and those in which it is heated in a fire passing, with the products of combustion, into the cylinder. Stirling's historic engine was the first of the first-named group, and Ericsson's the first of the last-named. In the first, the air can be exhausted, and fresh air supplied for each cycle. In the second, the same air is used over and over again, passed through a regenerator of metal work. In the first no regenerator is required.

The weight of such engines per horse power is greatly in excess of that of steam and gas engines. Difficulties arise due to the high temperatures, which burn the working parts, and which render lubrication by ordinary methods difficult, graphite being used in preference. Others arise from leakage of air at joints, and glands; and the scoring of parts. It would not do, however, to judge modern air engines by the earlier types.

The Ryder engine belongs to the regenerator class, the same air being used repeatedly. It has two vertical cylinders, one, the power cylinder in which the air is heated, being larger than the displacer cylinder. A plunger, or long ram-like piston, works in each, and a connecting rod from each is coupled to a crank at each end of the flywheel shaft. The cranks are at right angles, so that when one plunger is at the end, the other is near the middle of its stroke. There is a fire under the power cylinder to heat the air; the displacer cylinder is water jacketed, and there is a passage between the two, containing regenerators. There are no valves, but the hot air passes along this passage, and moves the displacer piston, doing work, and becoming cooled, with reduction of volume. The air, then driven out, passes through the regenerator back to the power cylinder, receiving heat from the regenerator, and a further supply from the power cylinder, to be again used.

Hot Blast.—Dr Percy cited the introduction of the hot blast as an example of an innovation, apparently of the most trivial kind, which has influenced the destinies of the human race. Mr Mushet, in 1843, considered the invention of the hot blast as a means of developing natural wealth which might properly rank with that of cotton spinning by Arkwright.

The inventor of the hot blast, Mr James Beaumont Neilson, manager of the Gas Works of Glasgow, obtained his patent in 1828. It is curious that the blast furnace is not named first in the specification, but subsequently to the "ordinary smith's fire or forge," and "for a cupola of the usual size for cast-iron foundries," then "for fires, forges, or furnaces upon a greater scale, such as blast furnaces for smelting iron, and large cast-iron founders' cupolas." Even the temperature of the blast was not expected to be nearly so high as it subsequently became, the specification stating that "it is better that the temperature be kept at a red heat or nearly so, but so high a temperature is not absolutely necessary to produce a beneficial effect." The use of hot blast effected so marked an economy in the smelting of iron that by the year 1835 it was in operation in every ironworks in Scotland except one, in which it was being introduced.

In an action at law in 1843 by Neilson against W. Baird & Co. for refusal to pay license for permission to use hot blast, the defendants admitted that in ten years they had made £260,000 net profit on hot-blast iron, and in one year (1840) £54,000 net profit!

It is curious that previous to the introduction of hot blast, it had been a common belief with ironmasters that the colder the blast the better, due to the fact that the product of the furnaces was greater in winter than in summer. This is now known to be due to the greater moisture in suspension in the atmosphere in the summer than in the winter. *See* **Blast—Dry Air.**

To heat the blast was therefore in opposition to the ideas of that period. Even after its introduction the heating up was of slow development, from about 200° Fahr. in 1829, and 300° in 1830 at the Clyde Ironworks, to 1,500° at the present time. Cast-iron pipe stoves have had to give place to regenerative stoves of brick. The success of the method was great at the beginning, for the hot blast reduced three times as much iron as the cold, and coal instead of coke could be used.

On first thoughts it does not seem that there could be any more advantage in using fuel to heat the blast than in using it in the furnace. But to understand the gain, the loss of heat in converting a large proportion of the carbonic oxide, CO, say one-third, produced by the combustion of the carbon into carbonic acid, CO_2, must be remembered. The heat obtained by burning a unit of carbon in heating the blast is more than three times as great as that yielded by burning a unit of carbon in the furnace. The combustion of carbon by air in the blast furnace generates 2,473 heat units, while the complete combustion secured by heating the blast generates 8,080 units. Cold air introduced at the tuyeres produces the imperfect oxidation CO_2, which is decomposed into CO higher in the furnace. Hot air produces CO in the vicinity of the tuyeres, and yields a higher temperature than CO_2 does, notwithstanding that the heat generated by burning carbon to CO_2 is greater. The reason is best tersely stated in the words of Sir I. Lowthian Bell, as the result of his classical investigations on this subject—"The combustion of a unit of carbon burnt to carbonic oxide in a blast furnace of 80 ft. gives nearly as good an effective result, although it evolves only 2,400 calories, as the same quantity of carbon burnt to carbonic acid in a low fire, although in the latter case 8,000 calories per unit of carbon are generated. There is, however, this marked difference between the two examples, that whereas the 7,992 heat units referred to in the case of the blast furnace are almost all usefully employed, a very large proportion of the 8,000 evolved in the low hearth escapes into the air unutilised. In the low fire, as experience tells us, there is an enormous waste of heat which is indeed visible in the flame, and incandescence at the surface of the fuel. On the other hand, in a blast furnace of 80 ft. the materials are, it is true, red hot for more than 50 ft. above the hearth, but the upper surface of the materials instead of being red hot, exhibit little or no signs of incandescence, proving a comparative freedom from waste due to this cause."

Results of the use of hot blast are the utilisation of taller furnaces, of larger hearths, a better distribution of heat, and heavier burdens. A secondary result of increased temperature in the vicinity of the tuyeres is the necessity for water-cooled tuyeres. There are several limitations to the temperature which can be economically used. Sir Lowthian Bell considered that 1,600° to 1,700° Fahr. was the practical limit, at which $19\frac{1}{2}$ cwt. of coal would be used for smelting a ton of Cleveland foundry iron. He estimated the gain between using blast at 1,000° Fahr. and 1,700° Fahr. at only 1 cwt.

Hot Blast Stoves.—The stoves, or ovens used for heating the air supplied to blast furnaces. These have gone through several stages of evolution, the earlier forms of which have only an historic interest. The first stoves comprised wrought-iron heating chambers set in brick-work, with a fire-grate below, and the pipes through which the air was transmitted passed through these heated chambers. In some, each tuyere was supplied by its own separate stove. Afterwards the single large stove was adopted, but divided into separate compartments for the air to pass through them in succession. The expansion of the pipes gave trouble, hence in many cases the pipes were arched over the fire-grate. Circular ovens followed in various designs, with pipes of U shape standing vertically on the blast mains. In the *pistol pipe* stove, a series of single pipes, enlarged at the upper end like the butt of a pistol, are divided nearly to the end by a rib, so making practically two pipes of each, the air passing up one side of the rib and down the other. Illustrations of all the old important types may be seen in Dr Percy's work on "Iron and Steel." At present the only interest lies in the regenerative stoves.

All the early stoves were heated by the combustion of solid fuel. About 1845, successful

attempts were made to heat the air with the waste gases from the blast furnaces, and for several years both systems existed side by side. But the real era of heating by waste gas came in with the invention of the Cowper regenerative stove in 1860.

The Cowper Stove.—This, Figs. 191, 192, comprises a tall cylinder, about 55 feet high by about 25 feet in diameter, built of steel plates, and lined with several courses of fire-bricks, including the dome with which the top of the stove is closed. Within the casing, and touching one side of it, a circular flame flue A is built of brick, and extends nearly to the dome. The remainder of the casing which is not occupied by the flame flue is fitted with brick chequering supported on girders and grids. At the base of the stove are situated the various valves, as follows:—The gas valve B, air valve C, the cold blast valve (not shown), the hot blast valve D, and the chimney valve E. If the valve to the chimney is opened a draught is created. At the same time the gas valve, and air valve are opened; the first admitting the waste gases from the blast furnace, and the second the air necessary for their combustion. These ignite at the base of the flame flue, and are split up into currents by vertical divisions. Thence the flame, being deflected by the dome, passes down through the chequer work, heating its upper portions to redness and cooling as it

Fig. 191.—Cowper Hot Blast Stove. (Barrow Hæmatite Steel Co., Ltd.)

descends, to pass away spent into the chimney at a temperature of about 400° Fahr.

The stove is now ready for the introduction of the cold air for the blast. The gas valve, air valve, and chimney valve are now closed, and the cold and hot blast valves are opened. The cold air enters the stove at the bottom, and passing slowly up through the brick regenerators is heated, and passing down the flame flue goes out by the hot blast valve to the blast main, leaving the stove at the temperature required, 1,500° Fahr. or thereabouts. The stove parts with its heat slowly, so that in two hours

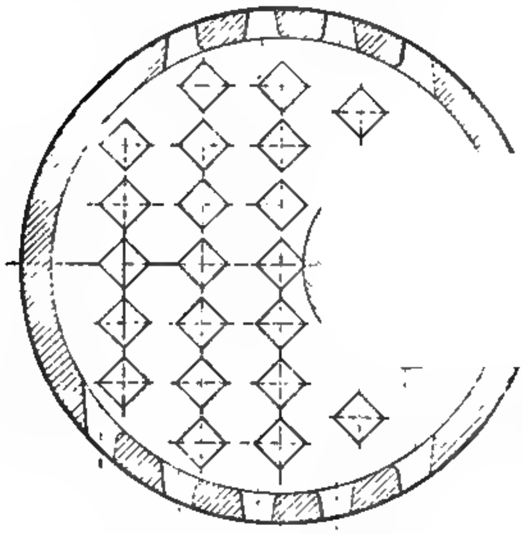


Fig. 192.—Section of Hot Blast Stove.

the lowering of temperature does not exceed about 200° Fahr.

The stoves are used in pairs, so that while one is being heated with the waste gases, the other is heating the blast. The advantages of the Cowper stove over the pipe stoves are great; the yield from furnaces having been increased by 20 per cent., temperature being raised from 1,000° to 1,400° Fahr. with two-thirds consumption of waste gases. A trouble which arises in working the Cowper stoves is the accumulations of dust which choke the brick-work and passages. Release valves are used to get rid of this, causing sudden expansion of the compressed air in the stove. In others a cannon is fired with blasting powder.

The Whitwell Stove.—This was introduced in 1865, and is of regenerative type, enclosed, like the Cowper, in a vertical brick-lined cylinder, some 65 feet high, by 25 feet in diameter. But the internal arrangements have no resemblance to the Cowper. The interior of the casing is occupied with a number of vertical brick walls separating narrow vertical chambers which communicate with each other at top and bottom. The air for combustion is not introduced at once to the gas, but through a number of feed passages between the partitions. The combustion therefore does not take place at once, but is going on during the passage of the gases up and down the partitions. The partition walls nearest the part at which the blast furnace gases first enter, becoming hotter than those farther away, are thicker than these. These stoves are worked in pairs, and the temperatures and reversals are similar to those noted in connection with the Cowper. They are more readily cleaned with scrapers through doors provided for the purpose.

The temperature of the blast is tested by a stick of zinc held in the blast, when the edges of the metal should melt in a few seconds. In the low temperature stoves a stick of lead is used similarly, or a bunch of dry twigs which should ignite at once. Various pyrometers are also used for the purpose. Automatic records of temperatures are taken in some cases.

Hot Iron Saw, or Hot Saw.—A machine for cutting off hot bars, using a circular saw running at very high speed, so that the bars are severed rapidly. Thus a 3-in. bar may be sawn through in four seconds. Fig. 193, Plate XIV., illustrates a common smithy type, with a saw 30 in. in diameter, driven by fast and loose pulleys at 1,500 revs. per minute. The work is placed in the vee bearings on the table, and the latter is fed up to the saw either by the hand lever to the left, or the treadle to the right, a counterweight causing return subsequently.

Another design of machine employed for heavy work has the saw running between bearings in a swing frame, depending from a housing, at the top of which pulleys on a horizontal shaft drive down by belt to the saw pulleys. The frame is moved to and fro by a lever, or by a steam cylinder.

A design of this character is illustrated in Fig. 194, Plate XIV. Instead of belt driving, a couple of 60 HP. electric motors are fitted on the framing. Belts drive down to the saw on either side. Its diameter is 5 ft. 6 in. and it is capable of sawing through a hot steel bloom 11 in. square. The saw is swung to and fro (pivoting around the axis of the motor shafts) by a hydraulic cylinder on the farther standard, operating a rocking shaft with levers and links connecting to the pendulum. A train of live rolls may be connected up to the base for conveying the hot bars to the saw.

Hot Liquor Pump.—A lift pump placed below the hot liquor being pumped, to prevent the pressure of steam interfering with the production of a vacuum.

Hot Metal.—Metal which is thoroughly melted, and is not allowed to cool down before pouring.

Hot Sand.—Patterns must not be rammed in hot sand recently knocked off the surface of castings, or the sand will stick to them, and the steam present may be injurious to the mould.

Hot Saw.—*See* **Hot Iron Saw.**

Hot Short.—Denotes a condition of wrought iron in which it becomes brittle at a welding heat, caused by the presence of sulphur.

Hot Water Systems.—Buildings may be heated by hot water, steam, either live or exhaust, hot air, or electricity; alternatively to open fires, or stoves, which are neither economical nor clean. Each of these systems has advantages and disadvantages of its own, so that the best to select in any given case will depend on circumstances. The present article has reference to the first named only.

The High-Pressure System.—Hot water heating includes two systems, the high, and low pressures. To the first named there are many objections, chiefly due to the unpleasant effects of the high temperature of the pipes. Its most suitable place is in enamelling, and japanning, and for drying and heating stoves, but these lie outside the sphere of the warming of buildings. In this system, coils of wrought-iron tubes, preferably of $\frac{7}{8}$-in. bore, are employed, enclosed in a casing distributed over a fire grate, and in the furnace, or heating chamber. Thence pipes pass up through the building to be heated, and down again to the boiler. The pipes are first completely filled by means of a pump at a point near the boiler until the water runs over an overflow provided. The pipes are then closed with a screwed plug, and tested to from 1,000 to 3,000 lb. per square inch. There is an expansion pipe, or air vessel provided above the level of the overflow, the object of which is to give room for the expansion of water with increased temperature, which is considerable, and has to be provided for in such small bore pipe.

The expansion tubes range from 2 in. to 6 in. diameter, their length and capacity vary with the quantity of water, and they must be strong enough to withstand the pressure. Water when heated increases in bulk. From 39° Fahr. to 212° Fahr. it expands by 1·043 times, or 100 gallons become 104·3 gallons; at 500°, to 122·3 gallons; and air space must be left in the expansion pipe for the increased bulk demanded by the whole apparatus at maximum temperature.

Coils bent from the same tube are, when

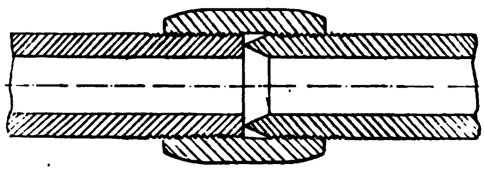


Fig. 195.—Joint for High-Pressure Pipes.

necessary, placed in the line of piping in rooms, and enclosed in ornamental casings. A gallon of water fills every 40 feet run of $\frac{7}{8}$-in. pipe. The pipe joints are made with screwed sockets, Fig. 195. One end is faced, the other tapered to a keen edge, which is made to butt against its fellow by the screwing up of a socket with right and left hand threads, using pipe tongs.

The circulation is rapid, and the heat given out is great, but the system is not so economical as it might appear to be apart from experience. The smell is disagreeable, and great care has to be exercised in making the fittings and in working.

The proportion of heating surface of the boiler coils, and the length of tube required for radiation, varies with the temperature required in rooms or stoves. Approximate figures are given by Mr Walter Jones in his work on "Heat-

PLATE XIV.

Fig. 188.—Horizontal Boring and Milling Machine, with Adjustable Heads and Travelling Table. (Collet & Engelhard.)

Fig. 189.—Horizontal Boring, Drilling, and Milling Machine. (Niles-Bement-Pond Co.)

Fig. 193.—Hot Iron Saw, Smithy Type. (Thomas Ryder & Son.)

Fig. 194.—Hot Iron Saw of Pendulum Type. (Henry Berry & Co., Ltd.)

To face page 206.

ing by Hot Water." The system is used where high temperatures of from 100° Fahr. to 350° Fahr. are required.

There is a modification of this system in which a supply cistern with a relief valve is substituted for the expansion tube, and this is sometimes preferred for temperatures not exceeding 100° Fahr., chiefly because, the water not being sealed, excessive pressure cannot occur.

The Low-Pressure System.—This is admirably adapted for the medium temperatures of 60° to 70° Fahr. required in dwelling houses and workshops. A boiler, of which there are numerous types, is located in the basement, and thence flow and return pipes complete the circuit of the building back to the lower part of the boiler. It is essential to efficiency that the boiler should be at the lowest point, because the mean temperature of the ascending column of water must be higher than that of the descending column; since the specific gravity of the latter must be greater than that of the former, in order to cause circulation. The greater the difference also in the specific gravities, the more rapid and efficient will the circulation be. Very approximately, for every square inch of area, the difference in weight is equal to one grain per foot of the vertical height of the column for each degree of heat. Mr Jones's rule is, for working temperatures ranging from 160° to 200° Fahr.: "The difference in degrees of temperature multiplied by the area of the pipe; and the product multiplied by the number of feet head of water, will give the approximate weight (in grains) that constitute the motive power."

As the head of water plays so important a part, efficiency can be increased by increasing the height of the pipes Another method is to increase their length and difference in temperature. A third is to reduce the diameter, in order to increase the cooling surface, which last is only of value within reasonable limits. Four inches is the usual size of hot-water pipes, and 2 inches the smallest cast.

Effects of Head.—The limit to the extension in height of piping is the increase in pressure. This is equivalent to approximately ½ lb. to the square inch, or exactly ·433 lb. for every foot in height. The result is, that if great head is necessary, as in tall buildings, the boiler, pipes, joints, and connections must be proportioned to the stresses, which become severe when about 20 ft. is exceeded.

Boilers.—The boilers used for hot water service are chiefly the saddle boilers, and the circular boilers, both horizontal and vertical, and which are made in dozens of various types. The saddle boilers are built in brick-work, as are many of the cylindrical boilers, but many are also independent. Boilers built in brick have side soot flues, some have a return flue, some have a draught to the chimney, and require much the same attention as Cornish boilers do. The saddle boiler made in wrought iron, and welded or riveted, or in cast iron is admirably suited up to 2,000 ft. of 4-in. pipe, plain boilers up to

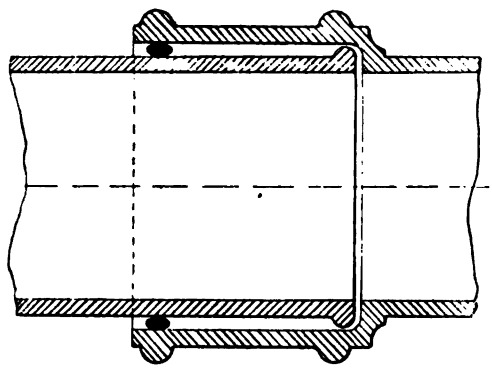


Fig. 196.—Socket Joint for Low-Pressure Pipes.

1,000 ft., and the chambered type up to 2,000 ft. For large quantities of pipe and for heads of water of over 30 ft., one of the cylindrical boilers should be used, because stronger. For very small installations, coil boilers are suitable, comprising a coil of pipes enclosed in a brick chamber over a fire-grate. The fuels used for heating boilers are coal, or coke, or a mixture of both, or rough slack, the latter being most suitable for banking up at night. Gas-fired boilers are also employed, chiefly for greenhouses and occasional use. They are too expensive in working for large installations. With regard to heating surface, a basis of one foot super. of direct heating surface for each 25 ft. run of 4-in. pipes is recommended.

Pipes and Joints.—Pipes are cast from 4-in. to 2-in. bore, below that they are made of

wrought iron. The larger pipes maintain a more steady temperature than the smaller. As the external surface radiates heat, that is made the basis of calculation. The superficial area of pipes is given in tables, or it may be obtained by a table of circumferences. Multiply the feet run by the circumference corresponding with the external diameter, and divide the result by 12.

The socket form of joint, Fig. 196, is usually preferred to flanged joints, because the latter cost more, and it is impossible to effect adjustments in length, which can be done readily with socketed and spigoted ends. Rubber rings are easily fitted in the sockets, sometimes cement or lead joints are made. There are special joints by different firms. In two kinds by Jones & Attwood, Fig. 197, flanged ends are clamped together with ring bolts, which compress india-rubber rings round the pipes. In one design, seen on the upper figure, the flanges are loose, in the other cast solidly with the pipes.

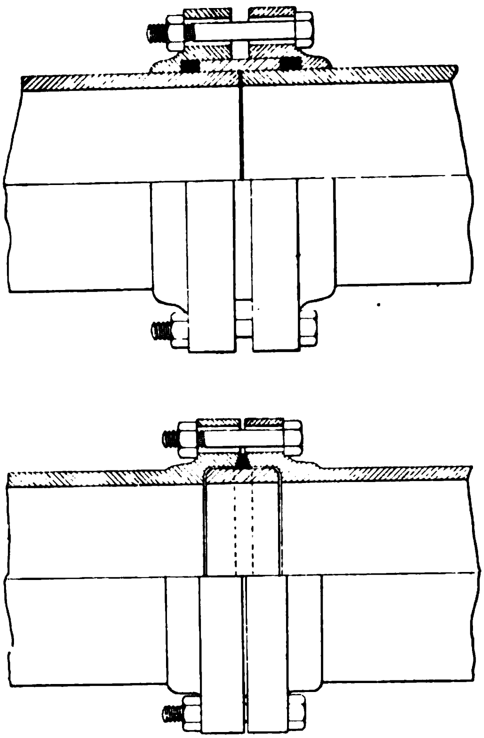


Fig. 197.—Flange Pipe Joints.

Radiation.—It is by radiation that the heat is transmitted from the pipes or coils into the room or workshop. The intensity of heat rays diminishes inversely as the square of the distance from the pipes or radiators. But the problem of radiator surface in relation to the contents of a room is a complicated one. Variations will occur due to the direction and force of the wind, though the temperature of the radiator and the air outside are unaltered. Humidity in the atmosphere makes more severe demands on the heating apparatus than dry frosty air does. Also, what is termed the *data*, or starting point for the heating up, makes much difference, since with increase of temperature more radiating surface is required to maintain a given temperature. The rules given for the estimation of the amount of radiating surface are contradictory. They are based on the cubic capacity of the room or building, on the cubic feet of air to be warmed per minute, on the superficial feet of glass surface, glass having much greater cooling effects than brick-work, or timber, and its equivalent in exposed walls, ceilings, &c.; and on the heat units emitted per square foot of heating surface per hour. Mr Jones has made these the subject of numerous experiments, and concludes that "No rule or combination of rules will be infallible." He has given a series of tables deduced from actual tests. His general rule for ordinary winter temperatures is; to obtain 60° Fahr. inside when 30° Fahr. outside, and water 170° Fahr. :—

Superficial Feet.		Superficial Feet, Radiation for 60° inside, when 30° outside.
Glass	÷ 6	Rooms under 5,000 ft. capacity.
Exposed wall	÷ 12	
Cubic capacity	÷ 120	
,, ,,	÷ 140	,, 5,000 to 25,000 ,,
,, ,,	÷ 150	,, 25,000 to 100,000 ,,
,, ,,	÷ 160	,, over 100,000 ,,

The above rule assumes the loss through doors, walls, and windows to be from two to three changes of air per hour. If more changes are required, add cubic capacity ÷ 300 for each additional change. For any other temperatures a table is given in the work, previously mentioned.

Coils.—These are designed to radiate heat in a small space where ranges of pipes would have an unsightly appearance. They are of wrought-

iron pipe, or cast iron, forming rectangular nests of pipes, through which the water takes a forward and backward course. Wrought-iron tubes are bent, cast pipes are united with flanges, or sockets, straight lengths to half circle bends. Box ends are more common, straight pipes entering sockets in the boxes. These are left uncovered in workshops, but enclosed in ornamental coil cases in public buildings.

Radiators. — These are more ornamental than the coils, and are made in many pretty designs, the pipes being vertical and often ribbed or gilled, with the object of increasing the radiating surface. Their heating surface is larger than that of coils, and they are more readily cleaned.

The figures illustrate some installations of pipes and radiators from the practice of Messrs Jones & Attwood. Fig. 198 shows a two-pipe circuit on one floor, the boiler being seen in the basement, and the four radiators above. The return from the radiators must not be made to the return main of a two-pipe circuit in the manner shown at A in the figure, when other radiators are on the same circuit, but the flow and return from the radiator must be made to the main flow pipes, as at B. It is preferable to use single circuit pipes of ample size. If two-pipe circuits are necessary, the flow and return from all radiators must be connected, preferably as at B, Fig. 199, on the main flow on the main return pipe. If connected as at A, short circuiting will result. Figs. 200, 201 show radiators in a four-storied building, either method being correct. In Fig. 200 an air pipe is required on top of each rising flow pipe, in Fig. 201 an air tap is necessary on each radiator.

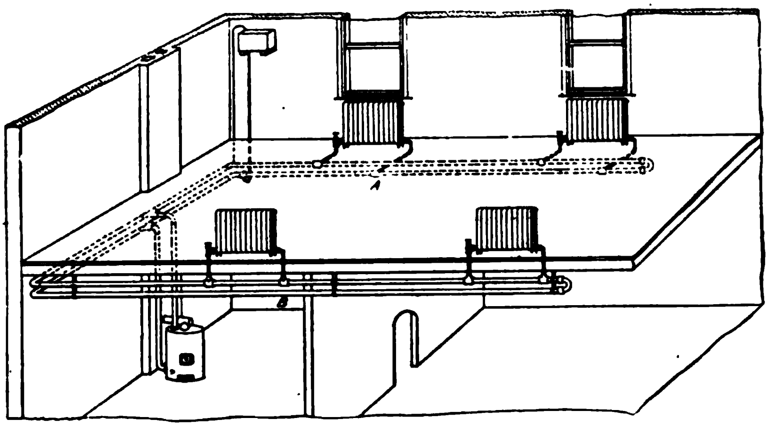


Fig. 198.—Two-Pipe Circuit.

Hot Water Test.—Used in steam boilers following the cold test, the hot water by causing expansion finding out the weak parts in the caulking.

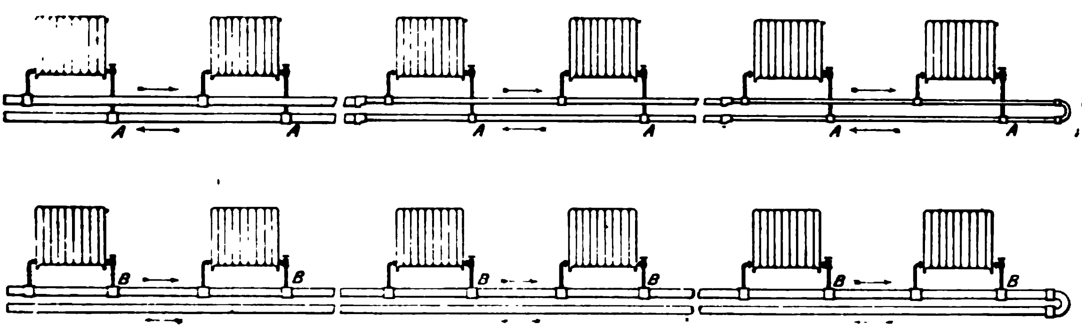


Fig. 199.—Radiators on Two-Pipe Circuit.

Hot Well.—The condensing tank which receives the exhaust steam from a jet condensing engine.

Hot Wire Ammeter.—An ammeter indicating the current passing through a stretched

wire, so arranged that, upon its becoming heated by the current passing, its expansion operates against the tension of a spring which in its turn moves an indicating pointer. The indication is thus in direct proportion to the lengthening by expansion of the heated wire, which is in some instrument, and long range readings of great accuracy can be obtained. Fig. 202 shows its action. A very fine platinum-silver wire w^1 is stretched across two fixed points 1 to 2. A compensating wire w^2 in parallel compensates for variations of outside temperature, as it is not

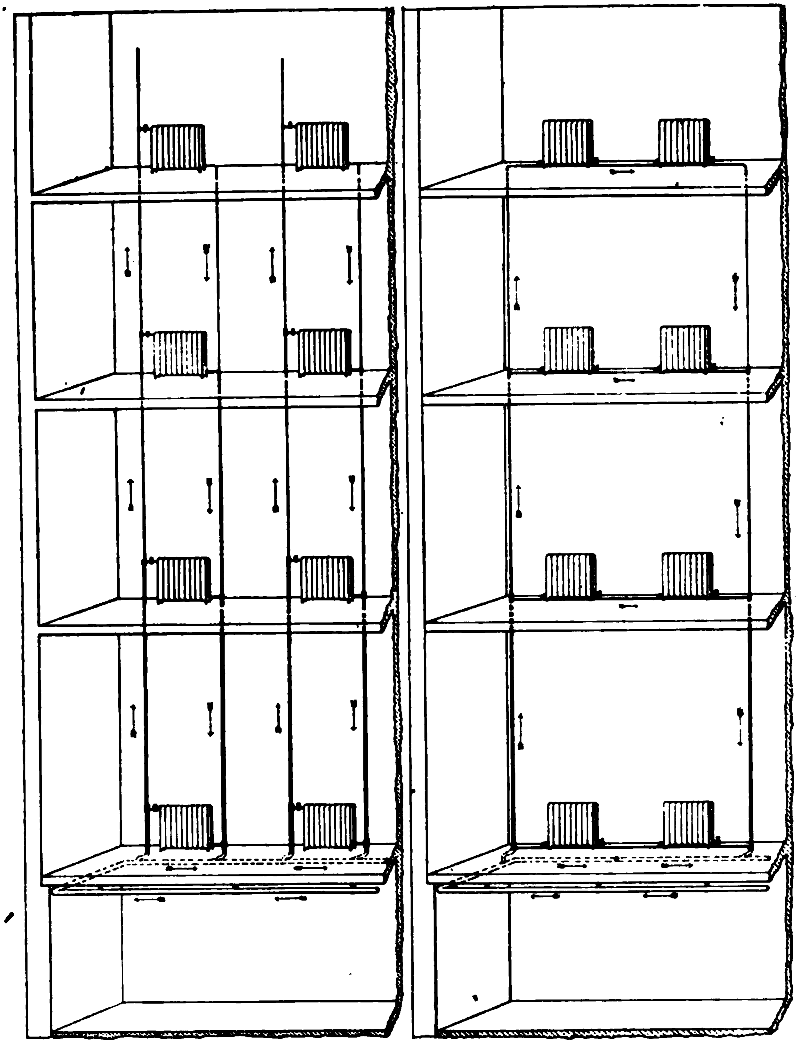


Fig. 200. Fig. 201.
Single Circuit arrangement of Pipes.

instruments carried in a long tube, so that a length of 10 to 12 feet of wire may be employed. Another type of hot wire instrument measures the sag produced by the heating of a short piece of wire. This is a shunted instrument, so that only a very small current passes through the electrically heated. To w^1 is attached a cord C, which passes round a pulley P, and is attached to the end of a spring S. P carries also a pointer N. When a current, therefore, passes in the mains, whilst the greatest portion of it passes direct through the shunt, a very small

amount also goes through the instrument. W^1 becomes heated by this current and a proportional sag is produced by the expansion of W^1. The spring S then pulls up the cord C, the pulley P revolves, and the pointer N is moved over the scale, thus directly indicating the amount of sag produced by the heating effect proportioned to the current carried by W^1.

There being no magnetic circuit, and also because alternating or direct currents produce similar heating effects, hot wire instruments may be used on either alternating or continuous current circuits.

Hot Wire Voltmeter.—A similar instrument to the **Hot Wire Ammeter.** When

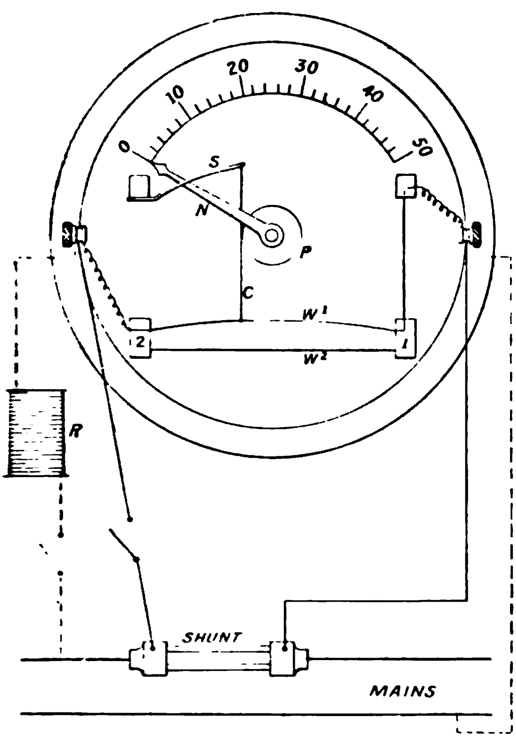


Fig. 202.—Hot Wire Ammeter.

used as a voltmeter the instrument is connected as indicated by dotted lines in Fig. 202. A very high resistance R is then placed in *series* with W^1 to reduce the current passed through the instrument.

The current (and consequently the heating and sag of W^1 and the indication of N) then depends upon the voltage of the main circuit. By Ohm's Law, $C = \frac{E}{R}$, and in this case R being constant, C varies as E, and therefore E across the mains is resolved by $C \times R$ at any moment.

H.P.—Horse power; or the high-pressure cylinder in a compound engine, or *High Press.*

Housing.—The vertical framing which carries the bearings of rolls, or the cross-rails of planers and boring mills.

Hub.—A boss encircling a shaft, and carrying the arms or spokes of a wheel. These may be either cast with the hub, or attached separately.

Hubbing.—*See* **Forging Dies.**

Hunting Cog.—An extra tooth in a wheel to prevent the same teeth coming into gear frequently. If the numbers of teeth in wheel and pinion have a common divisor, an extra tooth renders them primes to each other, without materially altering the velocity ratio. The object sought in the extra tooth is to avoid irregularity of wear.

Huntington Mill.—A crushing mill for quartz, comprising three vertical shafts, each carrying a loose roller at the bottom end, working against a steel ring. An iron casing surrounds the rollers, and supports a circular screen above the crushing area. The frame which holds the three roll shafts is rotated through the medium of gearing driving from below, actuated in the first place by a horizontal shaft with belt pulleys. The ore is reduced by the resulting centrifugal action, and passes through the screen to the amalgamating table. The rollers do not reach to the bottom of the casing, so that mercury may be employed. The mills range from 3½ ft. to 5 ft. diameter of casing. The wet method of crushing is followed chiefly.

Hydrant.—Usually a stand-pipe, with a ball valve, kept up against its seat by the pressure of water in the mains; and being thrust down by a screw operated by a tee handle, allows the water to flow up under pressure, supplying pipes or hose attached to nozzles at the top of the pipe.

Injector Hydrants, or *Fire Hydrants*, are the invention of Mr Greathead, the principle of which is the injection of a small jet of high-

pressure water obtained from hydraulic mains, at 700 lb. or more pressure per square inch, into a larger jet from the ordinary waterworks mains. Wherever the hydraulic mains are laid, the injector hydrant will perform the function of a portable fire engine. With a low-pressure supply of, say, 30 lb. per square inch, and a hydraulic power supply of 700 lb., a jet of water of 150 gallons per minute delivered through 200 feet of 2½-in. brigade hose with a 1-in. nozzle can be thrown to heights of 75 to 100 ft. About 25 gallons of power water are required to each 150 gallons discharged through the hose.

Hydraulic Bear—*See* **Punching Bear**.

Hydraulic Brake.—A brake in which pressure water is used to sustain a load in a hoisting machine, being more suitable than a ratchet and pawl and band brake in heavy machinery. The lifting cylinders in hydraulic cranes become hydraulic brakes during lowering. But the term relates to independent brakes used on steam cranes. A good example is the Matthews' design. In this the braking action takes place on the intermediate shaft, the piston rod of the brake cylinder working through a connecting rod to a disc on the shaft. The cylinder has a port at each end, and a piston with cup leathers, and the flow of water into it is controlled by a valve in a water passage adjacent, and parallel with the main cylinder. The position of this valve is controlled by a hand-wheel. The load is held up by closing the valve; or its rate of descent can be controlled by regulating its amount of opening, when the descent of the load forces the water through the valve backwards and forwards from one end of the cylinder to the other, the same water being used constantly. The pressure is so great that the cylinder becomes hot. In frosty weather the water must be run out at night.

Hydraulic Capstan. — *See* **Hydraulic Engine**.

Hydraulic Cements.—Limestones which when burnt cannot be slacked with water, but which if ground finely and made into a paste have the property of hardening under water. When a limestone will both slack, and harden under water, the term "hydraulic lime" is applied to the mixture. The latter is not of much value, having been superseded largely by mixtures of concrete. The cements and limes are made of various mixtures of lime and clay.

Hydraulic Cranes.—A very large group that have only one feature in common, the use of water as the motive power, at pressures of 750 lb. to 1,500 lb. to the inch; equal to 50 and 100 atmospheres respectively. These cranes are made for obvious reasons in fixed types, with posts and jibs. Within this limitation the designs and powers are numerous and extensive. An exception occurs in the cranes used for riveting plant and a few others, for which the water supply is brought through jointed or *walking* pipes.

Variations in design are due chiefly to three things, the range of operations of the cranes, the location of cylinders and rams, and the method of operation, whether direct or through multiplying pulleys and chains.

Range of Operations.—These are three in number; lifting, slewing or turning, and radial movements. A comparatively small number of true derricks are made to be operated hydraulically. But as a rule, it is better to employ horizontal jibs, with a racking carriage, or jenny. In any case a movement must have one actuating cylinder, as in lifting; and some, as turning, and racking, must in most designs have two. One suffices if a rigid rack forming a continuation of the ram turns a pinion. Without this, the two cylinders are required for motion in opposite directions. But in lifting, one suffices, because the load by its gravity returns the ram on release of the pressure water. It is in the cylinder arrangements chiefly that designs vary in cranes of similar types, and functions; for the position of the cylinders is of little importance, because their movements can be transmitted in any directions by guide pulleys. They are therefore found disposed horizontally, vertically, and diagonally, and often some are placed so as to afford counterbalance to the forward tipping movement of the crane. As the range of operations is generally larger than the stroke of the ram, multiplying pulleys are used with loss of power, but increase in speed. Two or three sets of pulleys are then arranged side by side.

The Location of Cylinders and Rams.—These must depend to a certain degree on the type of

crane. In the simplest wall cranes, the jib is merely a support for a portable hydraulic riveter, or a lift, or a puller. Either requires a carriage for the cylinder, which is pulled along the jib by hand, by an endless rope or chain actuating a sheave; and flanged running wheels, and jointed pipes for supplying the pressure water to the cylinder. The same device may be utilised in fixed post cranes, independent, or top-supported, in portable jib cranes, and overhead hand-travelling cranes. A wall crane which has the hoisting and racking motions actuated by cylinders and the slewing by hand,—pulling at the load, is shown in Fig. 203, Plate XV. The rake is 18 feet, and height of lift 8 feet.

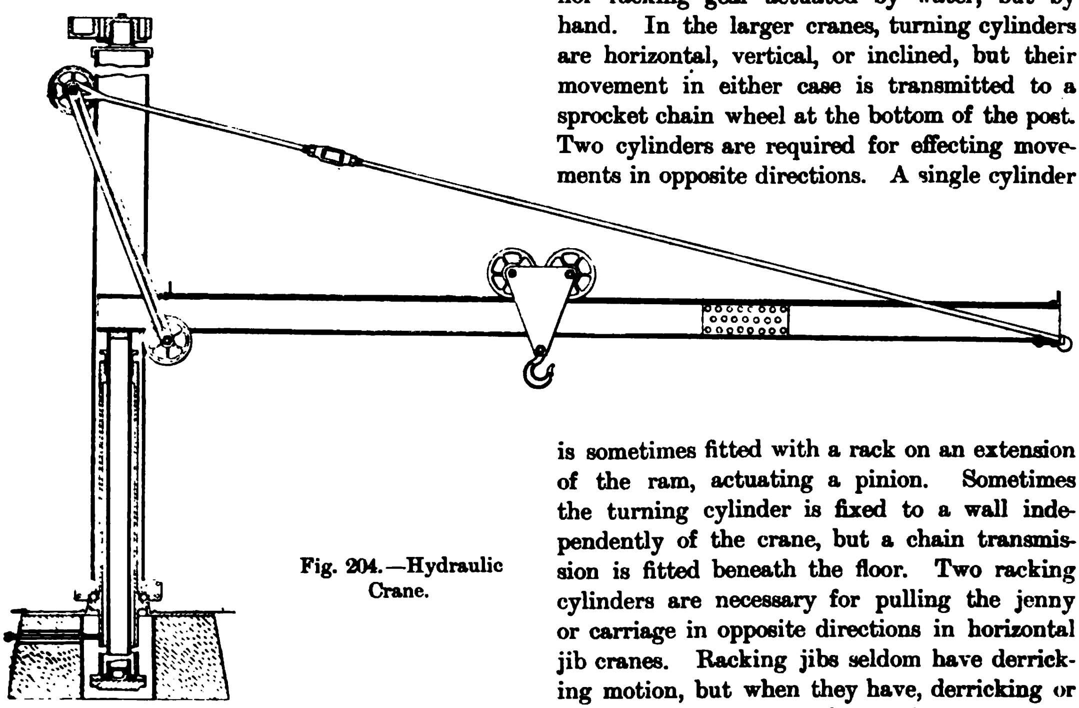


Fig. 204.—Hydraulic Crane.

Next, there are the jib cranes of independent type; that is, supported wholly on a base sufficiently stable, and those which receive support at the top as well as the base. These may be divided into two broad groups. In one, the jib is lifted and lowered directly, the amount of lift and descent being equal to the movement of the ram as in Fig. 204. There are many hydraulic cranes of the lifting jib type, notably those for ingot work, Fig. 205, Plate XV. The jib is raised upon a central ram, and the carriage with its load is racked across the jib by hand, the radius being 16 feet, and lift 6 feet. The range of lift in these is therefore limited. In the other, multiplying pulleys are used as in cranes for general service. The cylinders for lifting are located between the members that form the post, or to one side, or back, or front; or in some cases independently attached to a wall, and operating a wall crane.

Many light cranes have neither the turning nor racking gear actuated by water, but by hand. In the larger cranes, turning cylinders are horizontal, vertical, or inclined, but their movement in either case is transmitted to a sprocket chain wheel at the bottom of the post. Two cylinders are required for effecting movements in opposite directions. A single cylinder is sometimes fitted with a rack on an extension of the ram, actuating a pinion. Sometimes the turning cylinder is fixed to a wall independently of the crane, but a chain transmission is fitted beneath the floor. Two racking cylinders are necessary for pulling the jenny or carriage in opposite directions in horizontal jib cranes. Racking jibs seldom have derricking motion, but when they have, derricking or luffing cylinders have to be fitted.

In some cylinder arrangements the cylinder is made to move, but generally it is more convenient to let the ram move.

The location most favourable to the economies of hydraulic cranes are for service on wharves, where rows of cranes can be supplied from a common service. There are many such installations for very light and very heavy loads. The self-contained wharf crane, Fig. 206, Plate XV., has only lifting and slewing motions, operated by rams within the structure. The radius is 25 ft. A usual type of hydraulic wharf crane is that in Fig. 207, Plate XV.,

with fixed jib, and a limited range of ground movement by hand power, walking pipes being provided to allow of this movement. Two lifting powers, of 10 and of 30 cwt., are provided, the height of lift being 40 ft., with a jib reach of 25 ft.

An unusual type of hydraulic crane, running on the roofs of warehouses, is shown in Fig. 208, Plate XV. The rails are laid on the ridges and eaves of the buildings, and the crane is moved along by hand gear to any position required. The lifting and derricking are performed by cylinders lying within the sloping box going down the roof, and the slewing cylinders are located in the box girder forming the base of the carriage. The capacity is 30 cwt., lifted through a height of 76 ft., at a speed of 150 ft. per minute, and the derricking (or luffing) has a range of 43 ft. to 28 ft.

Hydraulic Engine.—The three-cylinder Brotherhood type is arranged for water pressure. Pressures may range from 60 lb. to 1,500 lb. per square inch. The engine as made by the Hydraulic Engineering Co., Ltd., of Chester, is illustrated by Fig. 209. It is single-acting, the trunk pistons and ball-ended connecting rods are therefore always in compression. The pressure water enters the pipe A, filling the chamber B. It passes through one of the passages *a* in the gun-metal valve C, and through the lignum-vitæ block D, thence through a passage E into one of the cylinders, pressing the piston F inwards. As the piston begins to move, and with it the connecting rod G, and crank H, and shaft K, the rotary valve C turns and opens another port to the water supply, and so on. The return or exhausting stroke of the pistons drives the water back, and out through the passages into the exhaust pipe J.

The piston, rotary valve, and other parts subject to the action of the water, are of gun-metal, excepting the port face, which is of lignum-vitæ. The cylinders and crank shaft bearings are shown bushed with gun-metal. The upper piston is provided with a lubricator filled through an opening in the casing, screwed caps being fitted as seen. The engine can be made reversible if desired.

Cylinders range in size from $1\frac{3}{16}$-in. bore, with $1\frac{3}{16}$-in. stroke, to 14 in., with 12-in. stroke. The one shown is a 4 in. × 4 in. for 700 lb. pressure. It will develop 9 B.H.P. at fifty-six revolutions per minute. An engine with $1\frac{3}{16}$-in. cylinder × $1\frac{3}{16}$-in. stroke, and 1,050 lb. pressure per square inch, will develop ¾ B.H.P. at 120 revolutions per minute. These engines are used for all kinds of service; for operating portable drills and other machines, for capstans, hauling tackle, penstocks, or sluices, fans, &c., &c.

Fig. 209.—Hydraulic Engine.

PLATE XV.

Fig. 203.—4-Ton Hydraulic Wall Crane.

Fig. 205.—2-Ton Hydraulic Ingot Crane.

(Henry Berry & Co., Ltd.)

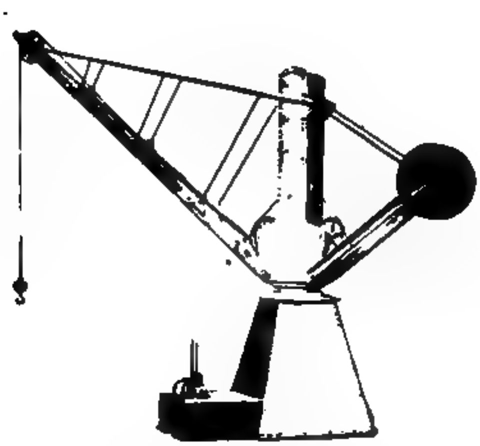


Fig. 206.—10-Ton Hydraulic Wharf Crane.
(Henry Berry & Co., Ltd.)

Fig. 207.—30-Cwt. Hydraulic Travelling Wharf Crane. (The Hydraulic Engineering Co., Ltd.)

Fig. 208.—30-Cwt. Hydraulic Roof Crane, Liverpool.
(The Hydraulic Engineering Co., Ltd.)

Fig. 211.—Four-Cylinder Hydraulic Engine.
(Henry Berry & Co., Ltd.)

To face page 214.

Hydraulic Capstan.—One of the most important applications of the above engine is to the operation of capstans. There are two types; the rigid, and the turn-over, the latter permitting of better examination of the engine when repairs are required. Fig. 210 illustrates one of the latter, made by the Hydraulic Engineering Co., Ltd., and fitted with Brotherhood's three-cylinder engine. The engine is contained within a cast-iron tank, bolted down to a foundation of concrete or masonry. This takes the place of a brick-lined pit, as used for rigid capstans, being necessary for the trunnion fittings required for turning over. These trunnions are seen in the view to the right, and through them the pressure and exhaust passages are carried. The worm wheel by which the turning is effected is seen at A. The worm, not indicated, is turned by an ordinary tee handle above ground. No joint is disconnected by turning. If these capstans are fitted on stagings, the tank is carried on joists. The engine shaft is prolonged to form the capstan shaft as seen in the view to the left, so that gears are not required. Speeds are varied by varying the engine speed. These are made for a working pressure of 700 lb. per square inch, in a range from ½ ton to 2 tons pull on the rope. The latter will haul 200 tons at 180 feet per minute on a good level railway. Dock capstans are made more powerful, with the engines driving through spur or bevel gearing.

Another application of hydraulic engines is shown in Fig. 211, Plate XV., being that of hauling machinery for dock caissons. Two three-cylinder engines are connected with pinions to a train of gearing (a portion only of which is shown) by which the caisson hauling chains are actuated. A load of 50 tons may be hauled at a speed of 25 ft. a minute, a working pressure of 600 lb. per sq. in. being used. The hand capstan seen in the illustration is for emergency use in case the hydraulic supply should fail.

Many reciprocating hydraulic engines have been designed and made. The disadvantages of these are the difficulty of regulation. To attempt to regulate the power developed results in reduced efficiency. The difficulty is due to the non-elastic character of water. As in reciprocating engines the piston speed varies between *nil* at each end to maximum at the middle of the stroke, the movement of the water is retarded and accelerated accordingly, and the pressure on the crank pin will vary. The back pressure due to the expulsion of the exhaust water is considerable. In some instances regulation is effected by throttling the water supply, in others by varying the stroke of the engine. A good type of horizontal reciprocating engines is shown in Fig. 212, Plate XVI. There are four cylinders, the two nearest the crankshaft being half the power of those in the rear. Each pair has a differential ram passing from one to the other, the fork end of connecting

Fig. 210.—Hydraulic Capstan.

rods being connected to these rams between the cylinders. The smaller cylinders are connected to constant pressure; the larger ones have a slide distribution valve operated by an eccentric. On the outward stroke water is admitted to the rear of the large rams, overcoming the resistance of the constant pressure on the smaller ones; on the in-stroke the larger cylinders are opened to exhaust, when the constant pressure on the small rams comes into play and completes the revolution.

Hydraulic Flanges, Hydraulic Joints.—Pipes for high-pressure water have thick flanges, the faces of which are registered or checked into each other, and in addition there are vee'd recesses turned on opposite faces. A ring of indiarubber, or gutta-percha is inserted between these, and being squeezed by the tightening up of the bolts maintains a close watertight joint. *See also* **Hydraulic Leathers.**

Hydraulic Force Pump.—A force pump used for high pressures, and employing a solid ram or piston instead of a bucket. The lifting of the ram results in a vacuum beneath, into which supply water rushes, which on the descent of the ram is forced out through a delivery pipe. As these pumps have to stand high pressures, they are generally made in gun-metal of good quality, and in the smaller sizes bored out of solid metal. The smallest pumps used for testing are generally mounted on a tank containing a supply of water, and they are hand-operated by a lever. The larger pumps for supplying accumulators, &c., are belt-driven.

Hydraulic Forging Press.—*See* **Forging Press.**

Hydraulic Gauge, or **Hydrostatic Gauge.**—A dial gauge for indicating water pressures in pounds per square inch, and usually up to 25,000 lb. The same design as in steam-pressure gauges is followed, with a curved tube. It is necessary where sudden fluctuations in pressure occur to fit a check valve in order to preserve the gauge from damage by shock.

Hydraulic Governor. — *See* **Turbine Governor.**

Hydraulic Hoist, or **Lift.**—A large class of machines made in very large and very small dimensions, and having in common perpendicular movements only. The same kind of machines are often indifferently termed hoists and lifts. Often, however, the first named relates to heavy goods only, the second to passengers or light articles, irrespective, however, of the dimensions of the hoist or lift.

These machines may be operated by low-pressure water from street mains, ranging from 30 lb. to 80 lb. per square inch, and used direct; or from a tank at the top of the building, when it can be pumped back and used over again. High-pressure water from an accumulator is used also at 700 lb. to the square inch. The dimensions of the ram and pipes are less in this case. Another distinction is that between direct-acting, and suspended lifts. In the first the height of lift and stroke of ram are alike, so that in high lifts the cylinder must be sunk deeply into the ground. In the second, ropes pass from a jigger, or multiplying cylinder of short stroke to the top of the lift. This avoids the deep excavation for a cylinder, but it is not so safe, and it entails overhead work and ropes.

An example of a hoist operated by a cylinder with multiplying ropes is shown in Fig. 213, Plate XVI. There is an automatic stopping gear, to prevent the cage from being lifted too high.

Though the perpendicular movement is the characteristic of nearly all hoists, exception occurs in inclined goods lifts, and inclined wagon hoists where circumstances render a direct lift impracticable. But direct vertical hoists are made in large numbers for coal wagons at depôts, goods yards, and gas works, for taking wagons from one level to another.

The direct-acting method is employed with one or more rams beneath the wagon platform. In Fig. 214, Plate XVI., three rams are used, working in cylinders sunk below the ground level. The load is 20 tons, lifting being done to 21 ft. height. A massive buffer beam is hung with chains in such a way that it blocks the opening when the platform is at a different level. An arrangement is provided for forcing water back into the pressure mains by the action of a loaded wagon descending. In cases where the lines of rails are not directly above one another, the *inclined* or *skidway* hoist is

used, having a carriage of triangular form, and moving by wheels up and down inclined rails. The top of the carriage is level, to carry the wagon. A hydraulic jigger lying between the rails provides the lifting power, through the medium of chains. A hydraulic capstan is provided at each line of rails to haul the wagons on and off the platform.

Hydraulic Jack. –*See* **Jack.**

Hydraulic Jigger.—A portabl machine for loading and unloading goods from ships and warehouses. It i by a hydraulic ram A, Fig. 215, set at to save head room, and carried betwee built up of angles. As the ram is n wards it draws the chain over a smal on a shaft which carries a large rop whence the hoisting rope is led over a guide pulley to the load. The operations are controlled by the lever D.

Hydraulic Joints.—*See* **Hydra Flanges.**

Hydraulic Leathers.—The pack used for hydraulic rams, pump buc &c., to prevent escape of water betw the moving parts and the cylinders. Hemp packings though cheaper are only suitable for low pressures, as they become torn, and produce excessive friction by the necessity for screwing up the glands very tightly. Moreover the pressure is constant whether a ram is working at low or high pressure, while that of a leather is proportional to the actual pressure for the time being. Hemp scores the rams more than a good leather does. There are three shapes used; the cup, the hat, and the U.

The Cup Leathers.— Also termed *bucket* leathers, because they are commonly used for pump buckets, are shown in Fig. 216, A to C, with their methods of attachment. If a single leather is used it is retained with a guard ring and bolts, B. A space is left between the inside of the leather and the bucket body, and the water having access thereto presses the outside of the leather against the bore of the barrel or cylinder. If two leathers are employed, as in force pumps, where the water acts in both directions of the plunger, they are placed back to back, C (left hand), and confined by a guard plate, and water space is left, as in the bucket. Or, the end of the ram is prolonged to the size of the hole in the leathers, and the latter are confined with a circular nut screwed over the end projection, C (right hand).

The Hat Leathers.—Also termed *billy-cock* leathers, D. These are used for rams of force

Fig. 215.—Hydraulic Jigger. (Glenfield & Kennedy, Ltd.)

pumps in a stuffing box confined by a gland. It is not a favourite form, being rigid by comparison with the others, and producing more friction.

The U Leathers.—Also termed *double* leathers, *cupped* leathers, *neck* leathers, *press ram* leathers, E. This form is inserted in the cylinder body of the ram, and the latter works against it. It is bent, M, and pushed into a recess in the solid, F, or is confined in a stuffing box, by a gland, G, H. The interior of the U is occupied by a ring, G, which, however, leaves clearance space for the pressure of the water to take effect. Previous to the insertion of a leather, the inner space should be filled with neats' foot or sperm oil for an hour. Leathers have their edges bevelled to about 30°, a very important detail in working, as the edge must be sharp.

Moulding Leathers.—The leather used for packings is of the best quality, cut from middles, soft and free from knots and pin pricks.

The soft part, or the flesh side, must be pared off, leaving the thickness from $\frac{3}{16}$ in. to $\frac{5}{16}$ in., and which must not exceed the thickness allowed for in the pressing moulds. Differences of opinion exist as to which side should take the wear. Dies are shown in Fig. 216, J, K, L, for the different leathers as made in the shops, though many prefer to buy the leathers ready for use. In the cup form, A, a punch may hours to dry in a warm room, as a boiler or engine house. The bevel is imparted in a lathe, or with a knife subsequently to the removal of the leather from the dies. The hat leather is formed by pressing an annular die over a boss die, after which the centre is cut away. The U leather has to be made in two stages. In the first, a cup shape is produced between the dies shown in Fig. 216,

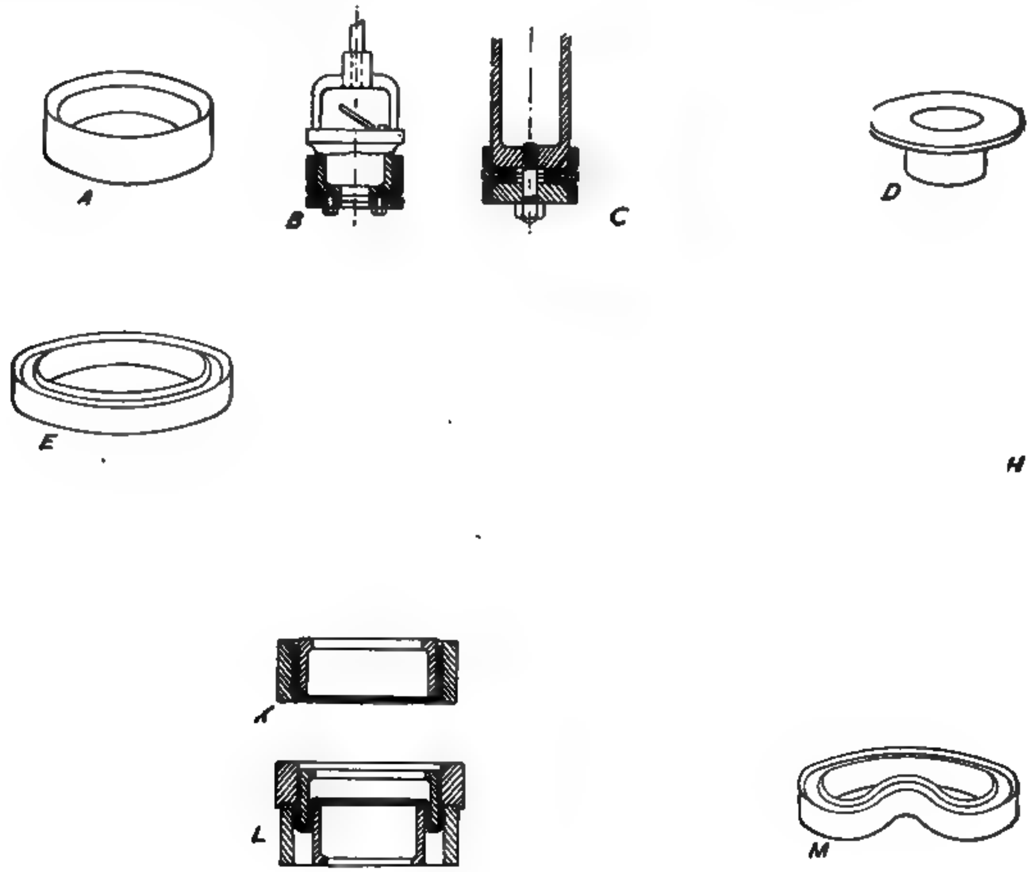


Fig. 216.—Hydraulic Leathers.

be used to press the leather into the bottom die, or it may be squeezed in by turning a nut on a bolt, J. A square head at the bottom of the bolt holds the die in the vice. The leather has to be first softened in warm water, working it between the thumb and fingers, and then rubbing tallow over it. After the squeezing is done in the dies, these, with the enclosed leather, are left for a few K; in the second, additional dies are inserted in the outer one just used, L; afterwards the central portion is cut away and the edges chamfered. There are differences in methods, but the foregoing are familiar. Some object to the bolt in Fig. 216, J, on the ground that the leather is apt to draw away from the hole. When large numbers are required an hydraulic press is to be preferred. But

PLATE XVI.

Fig. 212.—Hydraulic Engines Applied to Caisson Hauling Gear.
(The Hydraulic Engineering Co., Ltd.)

Fig. 213.—Hydraulic Hoist.
(Henry Berry & Co., Ltd.)

Fig. 217.—Direct-acting Hydraulic Pumping Engine.
(Henry Berry & Co., Ltd.)

Fig. 214.—Direct-acting Hydraulic Wagon Hoist.
(The Hydraulic Engineering Co., Ltd.)

To face page 218.

the dies can be manipulated in the vice, and screw clamps used instead of a central bolt. It will be noted that the leathers are pressed from solid discs, though holes have to be cut afterwards. It is difficult to press a leather from a ring, and it is not necessary to do so, because the central piece which is cut out can be utilised for pressing smaller leathers from.

Leathers become torn by the friction of corroded rams. These again score the rams, especially when gritty water is used. The remedy is to use clean water, to lubricate, and to keep the ram bright. When possible, the ram may be sheathed with brass or copper. When replacing a worn leather with a new one, rub the latter with dubbin or tallow, or neats' foot oil. If this does not soften it, warm water may be used, but if so it must be inserted in its place at once or it will go out of shape. If a wet leather is taken out, to be replaced, it must be put into a mould until it can be replaced, otherwise it will not retain its shape.

Hydraulic Lift.—*See* **Hydraulic Hoist.**

Hydraulic Main.—*See* **Gasmaking.**

Hydraulic Mean Depth.—The ratio of the cross sectional area of a stream to the length of the wetted perimeter, thus:—

$$\text{Hydraulic mean depth} = \frac{\text{area of cross section}}{\text{wetted perimeter}}.$$

The friction of a stream in a channel, or of water in a pipe, will vary inversely as the hydraulic mean depth, because the resistance of a channel or pipe is directly proportional to the extent of the wetted surface in a given length, and inversely as the cross sectional area. Sometimes termed "hydraulic mean radius," or "hydraulic radius."

Hydraulic Mining.—A method in extensive use in North and South America in which a jointed nozzle, termed a "hydraulic giant," or "monitor," is used to direct a stream of water against auriferous soil, breaking it down preparatory to submitting it to processes for the extraction of the gold. The water is brought under a head of several hundreds of feet in flumes or in pipes, and utilised in the monitor. It is made in different designs, with joints, and ball bearings to swivel to any angle. The weight of the nozzle end is counterbalanced, and nozzles of two different sizes are fitted to the machine.

Hydraulic Press.—*See* **Baling Press, Forging Press,** &c.

Hydraulic Puller.—*See* **Jack.**

Hydraulic Pumping Engines, Hydraulic Pumps. — Ram pumps which are driven by steam engines; all self-contained on a single bedplate, or pumps alone with provision for driving from an independent source of power through belts, or through gears from a shaft coupled to the first gear shaft, or by motor. Pumping engines are made in many types, vertical, and horizontal, simple, compound, and triple expansion. Pumps are arranged to be driven from a three-throw crank, or directly from the piston; and singly, or in tandem. The pressure against which pumps work is generally from 700 to 1,500 lb. per square inch. The efficiency is high. In the case of the engines of the Rotherhithe station of the London Hydraulic Power Co. it was 83 per cent.; being the ratio of the horse power in the water pumped, to the total horse power developed in the steam cylinders. In Fig. 217, Plate XVI., a set of direct-acting hydraulic pumping engines is shown. There are two steam cylinders working four single-acting rams.

Hydraulic Rail Bender. — *See* **Rail Bender.**

Hydraulic Ram.—A machine which raises water from a lower to a higher level by taking advantage of the kinetic energy of water in small increments. Water coming with a force due to head is brought into the ram through a drive pipe, Fig. 218, A. It encounters a valve, the *dash* valve, B, opening downwards, which falling by gravity is closed by the momentum of the water, which then passes on under pressure due to its momentum, and raises a second valve, C, opening upwards, communicating with an air vessel and delivery pipe. When the cushioning by the air in the vessel overcomes the pressure of the water, the latter is ejected through the delivery pipe. Then the pressure due to momentum being expended, the dash valve drops, allowing water to flow out of it, until the pressure rising again, more water is delivered. This action goes on from 40 to 200 times in a minute.

Falls of from 18 inches to 100 feet can be utilised in hydraulic rams. They will raise from 300 to 500,000 gallons a day. Water can be forced up as high as 1,000 feet.

Hydraulic Cylinder and Ram.—The term hydraulic ram is also applied to the ram and cylinder which utilises the high pressures required for hydraulic cranes, accumulators, &c. An illustration is seen under **Accumulator, Ingot Crane,** and other heads.

Hydraulic Formulæ (Tweddell).

When using a pressure of 1,500 lb. per square inch—

W = Total pressure required on ram in tons.

D = Diameter of ram in inches.

A = Area of ram in square inches.

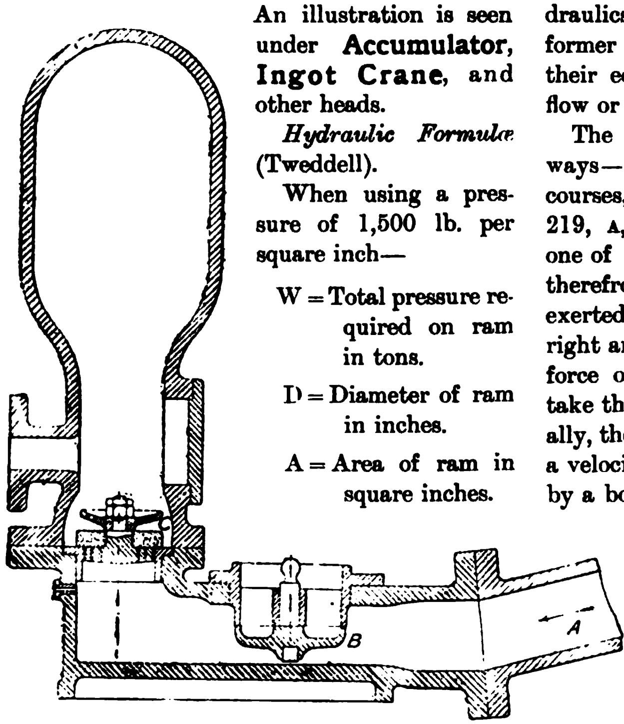


Fig. 218.—Hydraulic Ram. (Glenfield & Kennedy, Ltd.)

Thus approximately—

$$W = 0{\cdot}5\ D^2.$$
$$D = 0{\cdot}6695\ A.$$
$$A = 1{\cdot}494\ W.$$

Horse power transmitted without appreciable loss by friction at 500 lb. per square inch, pressure velocity 5 ft. per second—

Bore (inches)	0·5	0·75	1·0	1·25	1·50
Horse power	2·67	6·0	10·7	16·73	24·0

If D = diameter of ram of hydraulic cylinder in inches, then contents in gallons per foot run $= \frac{D^2}{30} = {\cdot}033\ D^2$ approximately.

At 1,500 lb. per square inch, each gallon pumped into the accumulator very nearly equals one horse power actual.

Hydraulic Riveting.—The closing of rivets by machines actuated by water pressure, usually at 1,500 lb. per square inch, done in fixed and portable machines of numerous types. *See* **Riveting Machines.**

Hydraulics.—Both hydrostatics and hydraulics deal with the subject of liquids, the former being confined to questions concerning their equilibrium, the latter treating of their flow or motion; hence termed *Hydro-dynamics.*

The flow of water may occur in a variety of ways—through orifices and pipes, along water-courses, and over falls. If a small hole, *c*, Fig. 219, A, be cut in a thin plate which forms one of the walls of a tank, the water will issue therefrom as a horizontal jet, since the pressure exerted by water is always in a direction at right angles to the surface it acts against. The force of gravity, however, compels the jet to take the form of a parabolic curve. Theoretically, the water should issue from the orifice with a velocity equal to that which would be acquired by a body falling under the action of gravity from *a* to *b*, from the surface level of the water to the level of the centre of the orifice. This vertical distance is called the *head.* So that the velocity should equal $\sqrt{2 \times g \times h}$, where g is the acceleration due to gravity, 32·2 feet per second, per second, and h is the head *a* to *b*. If, too, the theoretical velocity be multiplied by the area of the orifice, denoted by the letter *a*, the product would represent the theoretical discharge. Thus:—

$$\text{Velocity} = \sqrt{2 \times g \times h}.$$
$$\text{Discharge} = a \times \sqrt{2 \times g} \times h.$$

But various disturbing factors enter into the question, and these values have to be considerably reduced before they approximate to the truth. As the particles of water approach the orifice they acquire velocity, and in making their exit into the air they form a curve such that, at a certain distance from the orifice, the cross sectional area of the jet of water is less than the area of orifice. This contraction, called the *vena contracta*, occurs at a distance from the orifice equal to about half the

diameter of the opening. Its area is ·62, that of the orifice. This quantity is therefore called the "coefficient of contraction." The issuing water has, too, attained its highest velocity in the *vena contracta*, and this is about ·97 of the theoretical velocity. The formulæ above have therefore to be modified by the use of these coefficients.

Velocity $= \cdot 97 \times \sqrt{2 \times g \times h}$.

Discharge $= \cdot 62 \times a \times \cdot 97 \times \sqrt{2 \times g \times h}$.

By substituting the value of g, velocity $= \cdot 97 \times \sqrt{2 \times 32 \cdot 2 \times h} = \cdot 97 \times \sqrt{64 \cdot 4 \times h} = \cdot 97 \times 8 \cdot 03 \times \sqrt{h} = 7 \cdot 7 \times \sqrt{h}$, or roughly eight times the square root of the head. Similarly, discharge $= \cdot 62 \times a \times \cdot 97 \times \sqrt{64 \cdot 4 \times h} = \cdot 62 \times a \times \cdot 97 \times 8 \cdot 03 \times \sqrt{h} = 4 \cdot 8 \times a \times \sqrt{h}$, or roughly five times the area multiplied by the square root of the head. This rule is sufficiently correct for ordinary cases. But the discharge may be considerably affected by modifications in the shape of the orifice, and these modifications are briefly summarised below.

(1.) When the length of the opening is two and a half to three times its diameter, Fig. 219, (B) a (or least transverse dimension if not circular), the coefficient of discharge is ·81, and discharge $= \cdot 81 \times a \times 7 \cdot 7 \times \sqrt{h} = 6 \cdot 2 \times a \times \sqrt{h}$. Instead of a projecting tube, as in the illustration, the coefficient would be the same if the walls of the vessel were of the thickness e to f. (2.) But if the tube partly projects into the interior of the vessel, the coefficient becomes ·7. (3.) With apertures such as those in Fig. 219, (B) c, d, in which the sides converge at an angle of 6° in c, and 14° in d, the coefficient is about ·93. The area of orifice is of course the area of the opening g-h. (4.) Remarkably high coefficients are obtained by a modification of Fig. 219, (B) a, in which the inner angles are rounded off as shown in (B) b. Such orifices give coefficients as high as ·96 or ·97.

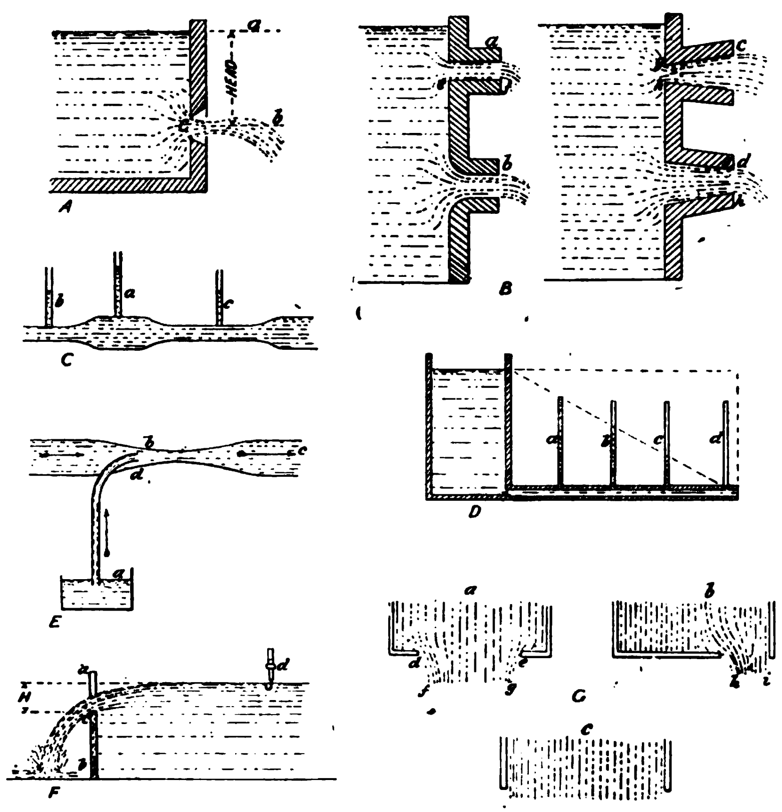


Fig. 219.—Hydraulics.

The flow of water through pipes is a highly complicated question, owing to the many disturbing factors which affect the flow. The total head is the distance (measured vertically) from the level of water in the reservoir to the centre of the opening from which the water is discharged into the air. The frictional resistance encountered by water in long pipes is very great, and the loss of head due to this cause equals by far the greater part of the total head. Various formulæ have been propounded by experimenters for the calculation of mean velocities or discharges, but the best give only an approximation to the truth. Roughness of

surface, deposits and incrustations, bends, bad caulking of joints, accumulations of air, lack of uniformity in bore, all combine to invalidate the result obtained even from the best formula.

The connection between sectional area and pressure in a pipe is shown by means of gauge glasses inserted as shown in Fig. 219, (C). Water rises in each tube, and the vertical height to which it rises reveals the head, producing the pressure at that point. In a long pipe of uniform bore a line joining the levels of water in a series of piezometers (or "pressure measures") (D) *a, b, c, d* would be quite straight, and would slope from the head to the orifice, which discharges into air as shown in the illustration. But if, as in C, the bore varies, the pressure as shown by the height of water in the tube is greatest where the diameter is greatest (at *a*), and least where the diameter is least (at *b, c*). That is to say, the pressure is least where the velocity is greatest, and *vice versa;* if a regular flow of water through the pipe is maintained, the velocity will be greater where the pipe narrows. Moreover, if (E) the end *c* be open, the pressure there is that of the atmosphere, and therefore the pressure at *b* is *less* than that of the atmosphere. If another pipe at *d* be connected with a tank of water *a* at the lower level, and *at atmospheric pressure,* it is obvious that a vertical flow of water will take place in the direction of the arrows. This is the principle on which Thomson's jet pump acts.

The velocity of a stream is measured in various ways—by observations taken in midstream if it be a large one, and by weirs and gauge notches in the case of a small stream. The velocity of a river or canal varies in different parts of its cross section, being greatest midway between the banks, and one-third below the surface. The greater the depth, the lower is the point at which the velocity attains the maximum, and *vice versa.* Roughly speaking, the mean velocity lies between four-fifths and nine-tenths of the surface velocity in midstream. The latter may be estimated by floating a piece of wood or corked bottle over a marked course, and the mean velocity by taking between 80 per cent. and 90 per cent. of the rate observed. Then volume = mean velocity × cross sectional area. The last-named factor is obtained by fixing a number of stakes or buoys at equal distances across the stream, and taking a sounding in each section. The average of these depths multiplied by the width of stream gives the cross sectional area. The average velocity may also be similarly found by ascertaining the velocity in each separate section. Many special instruments have also been devised for the calculation of velocity of flow. More or less satisfactory results have also been arrived at by mathematical calculation. Kutter's formula is used, but the selection of a correct coefficient allows so much latitude of opinion that the result is often nothing more than an approach to the truth.

A measuring weir is shown in Fig. 219, F. The water falls over the gauge notch made in the plate *a b*. There are several formulæ for calculating discharge; the Francis formula is—$Q = 3{\cdot}33\left(L - n\frac{H}{10}\right)^{\frac{3}{2}}$. L is the length of the weir, which is easily ascertained, H is the head of water, and *n* is the number of end contractions. The head is the distance H from the crest C to the level of still water. In practice the head is ascertained by means of a hook gauge *d*, which is placed a few feet back from the weir. A sliding rod terminating in an upturned hook is gradually raised towards the surface of the water until an almost imperceptible "pimple" of water is produced as it flows over the point. A scale and vernier then give readings to the hundredth of an inch. A weir, the plan of which is similar to that in Fig. 219, (G) *a*, is said to have two end contractions, *d* and *e*; *b* has only one end contraction; *c* has none, and is sometimes called a suppressed weir. As in the flow of water through orifices, it will be seen that a sort of *vena contracta* is formed at *f* to *g* and *h* to *i* (G), and so, as shown in the formula above, the length L of the crest is decreased, and one-tenth of the head must be deducted from the length for each such contraction.

Hydraulic Tools. — This term covers a wide range of appliances and machines which are actuated by water pressure. They are treated under the different heads in this work, and include presses of various kinds, for forg-

ing, flanging, bending, &c., riveters, punching machines and bears, jacks, shearing machines, rail benders, bolt and propeller starters, wheel presses, and other appliances of a more special character.

Hydraulic Tubes.—The stoutest steel tubes made, being about twice the thickness of common tubes, and solid drawn. Thus a tube 2 in. in the bore is $2\frac{3}{4}$ in. outside, a $1\frac{1}{2}$-in. tube is $2\frac{1}{16}$ in. outside. The tubes are screwed to Whitworth standard gas threads; and tees, elbows, and sockets, are made to suit. The joint for hydraulic tubes is illustrated on p. 206, Fig. 195.

Hydraulic Wheel Press.—*See* **Wheel Press.**

Hydrochloric Acid, HCl. Molecular weight, 36·37; density, 18·18.—The only compound of chlorine and hydrogen, which results on exposing equal volumes of chlorine and hydrogen to daylight. The commercial method is to heat sodium chloride (common salt) with sulphuric acid — $NaCl + H_2SO_4 = HCl + HNaSO_4$. The gas is very soluble in water. Impure acid (muriatic acid) is obtained as a by-product in the manufacture of sodium carbonate. It is also termed spirits of salts.

Hydro-Dynamics.—*See* **Hydraulics.**

Hydro-Extractor.—*See* **Centrifugal.**

Hydrogen (H).—Hydrogen is the lightest body known. The well-known class experiment of blowing soap bubbles and filling a gold-beater's skin balloon with this gas illustrates its lightness as compared with air. It is 14·4 times lighter than air, a litre weighing only ·09 gramme, is colourless, odourless, and tasteless. Liquid hydrogen boils at $-253°$, and freezes at $-257°$ Cent. Hydrogen does not support combustion. It burns with a bluish, feebly luminous, but very hot flame, which is often seen at the vent holes of foundry moulds, in which it is formed by the decomposition of moisture.

Hydrogen is produced by the action of dilute sulphuric acid on zinc:—

$$H_2SO_4 + Zn = ZnSO_4 + H_2.$$

Scrap iron is sometimes substituted for zinc.

Hydrogen (2 parts) combines with oxygen (15·8 parts) to form water, and may be liberated from the combination by the action of sodium and potassium when thrown on the surface of the water.

Hydrostatics.—Hydrostatics, strictly speaking, deals with the pressure of motionless water. The term is, however, sometimes made to include the question of the application of force to gases, *i.e.*, the science of pneumatics. Gases and liquids are related in that they are both "fluids," since, unlike solids, they flow. But while a given quantity of liquid possesses a certain definite volume which is practically unalterable by pressure, a quantity of gas has no definite volume, being not only highly compressible, but also having the power of indefinite expansion.

Liquids differ in the mobility of their particles, but this difference does not affect the laws governing action. Force applied to a viscous liquid such as tar or glycerine produces the same result as when applied to a mobile liquid such as alcohol, the only difference being that the mobile liquid is affected quicker than the viscous one, owing to less frictional resistance between the particles. A perfect fluid would be one in which there was absolutely no frictional resistance between the particles, and hence no resistance to change of shape.

Two highly important laws in hydrostatics are:—

(*a*) The direction of the pressure of a fluid on a surface with which it is in contact is perpendicular to that surface, Fig. 220.

(*b*) Pressure communicated to any part of a fluid is transmitted equally in all directions.

The first law has its bearing in questions concerning direction of pressure on dams, lock gates, retaining walls, and embankments. According to the slope of the surface, the water pressure may tend to overthrow, to lift, or to make the wall slide. The total pressure tending to bring about such results is the product of area of surface immersed, the depth of its centre of gravity below the surface of the liquid, and the constant 62·5, which is the weight of a cubic foot of water. In the case of a horizontal surface the total pressure equals area, multiplied by 62·5, multiplied by depth; but in vertical or oblique surfaces, since the pressure increases with depth, it is necessary to take the average pressure, that is the pressure at the centre of gravity.

The total pressure may be considered to act at the "centre of pressure." This is the point at which the resultant of the system of parallel pressures acts. In the case of a horizontal surface the centre of pressure is coincident with the centre of gravity; in the case of a vertical wall it lies at a distance of two-thirds of the depth below the surface of the water.

Since total pressure of a liquid against an immersed surface is only affected by area of wetted surface and depth of its centre of gravity, it follows, paradoxically, that the pressure is independent of the total quantity of water—a pint may exert the same pressure

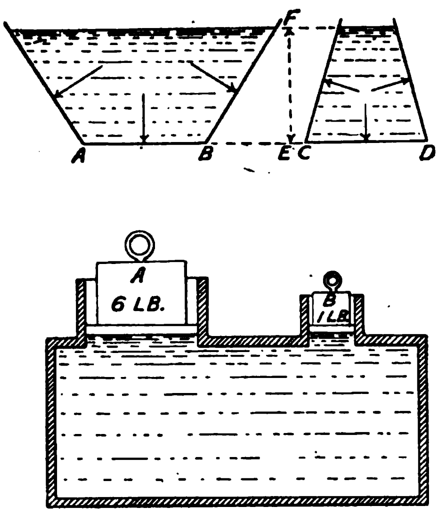


Fig. 220.—Hydrostatics.

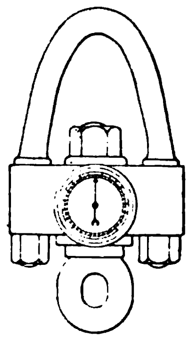
as a gallon. In Fig. 220 the horizontal surfaces AB and CD are equal in area, and the vertical depth FE is the same, and therefore the large quantity of water in the first vessel exerts no more pressure on the base AB than the comparatively small quantity in the second vessel exerts on CD.

The second law mentioned above underlies the principle of the hydraulic press. If in Fig. 220 in the lower illustration a pressure of 1 lb. be applied to the contained water, that pressure will be immediately transmitted undiminished, so that every portion of the surface of the vessel of area equal to that of cylinder B will receive a pressure of 1 lb., over and above the pressure previously sustained from the water itself. Now if the area of cylinder A is six times that of B, a weight of 6 lb. at A will be supported by the 1 lb. weight at B. In this way a pound weight may support a man. This ***hydrostatic paradox*** gives a clue to the cause of an accident that sometimes occurs in the laboratory or in the household. A flask or bottle is quite full of liquid, and an attempt is made to force the indiarubber stopper or cork further in. As a consequence the vessel bursts, though the pressure may have been merely that of a child's finger. A pressure of a few ounces on a small area becomes a total of many pounds when transmitted to the whole interior area. This, too, is the principle which explains the enormous power of the hydraulic press.

Common experience reveals the fact that all bodies weigh less, or appear to weigh less when immersed in water than when in air. The upward vertical pressure of the water appears to rob the solid of some of its weight. This vertical pressure is equal to the weight of liquid displaced by the immersed body (principle of Archimedes), and therefore the vertical pressure depends on the bulk of the body immersed. How much of a body will be immersed when placed in a liquid depends on its **Specific Gravity**. (1.) If the specific gravity of a solid and a liquid were the same, the solid would in theory remain immersed at rest anywhere in the liquid. (2.) If the specific gravity of a solid be greater, the upward pressure (equal to the weight of displaced liquid) will be overcome by the force of gravity and the body will sink. (3.) If the specific gravity of the solid be less, the upward pressure will force the solid to the surface, and it will float with more or less of its bulk out of water. This explains the apparently strange behaviour of heavy metals and stones in floating on the surface of mercury.

The weight, then, of any floating body equals the weight of the liquid displaced. If, therefore, we ascertain the number of cubic feet of water which a vessel and its cargo displace, and multiply that number by 62·5, the product is the weight of vessel and cargo. Conversely, given the dimensions of a vessel and its weight, the draught may be calculated. In a floating body the weight may be considered as acting

vertically downward through the centre of gravity of the body, and the upward pressure of the water through the centre of gravity of the displaced water. For equilibrium, the line joining the latter point (called the **Centre of Buoyancy**) with the centre of gravity of the body must be vertical. *See also* **Buoyancy** and **Metacentre**.



The practical applications of hydrostatic principles are seen in suction and force pumps, accumulators, hydraulic rams, jacks, cranes and presses, lifts, forging and flanging presses, wheel presses, bolt forcers, and so on.

Hydrostatic Weighing Machine. — A machine for automatically indicating the weight of a suspended article by the action of liquid pressure. Fig. 221 illustrates the Duckham machine, in external view to the left, and in enlarged section to the right. It comprises a cylinder filled with oil, suspended from a crane hook. The load is attached to an eye, the shank of which passes through a stuffing box to the piston above. The pulling down of the piston by the load drives oil into the tube of the pressure gauge, and the readings on the dial indicate the weight at a glance. These machines are made in capacities ranging from 1 to 100 tons, by the East Ferry Road Engineering Works Co., Ltd.

Hygroscopic Water.—That which is not in a state of chemical combination, as in fireclays and other absorbent bodies. It is driven off by the application of a moderate amount of heat.

Hyperbola.—The hyperbola is one of the conic sections (*see* **Cone**) formed when the intersecting plane cuts the base at a greater angle than the side of the cone makes.

To draw the hyperbola when the major axis AB and the foci C and C are given, Fig. 222:—Produce AB, and on the further side of C take points such as 1, 2, 3. With radius A1 and from centres C and C describe arcs at D, E, F, G. With radius B1 and same centres cut these arcs. With centres C and C and radius A2 describe other arcs at H, I, K, J, and cut them as before with radius B2. Repeat this process with each point beyond C, and

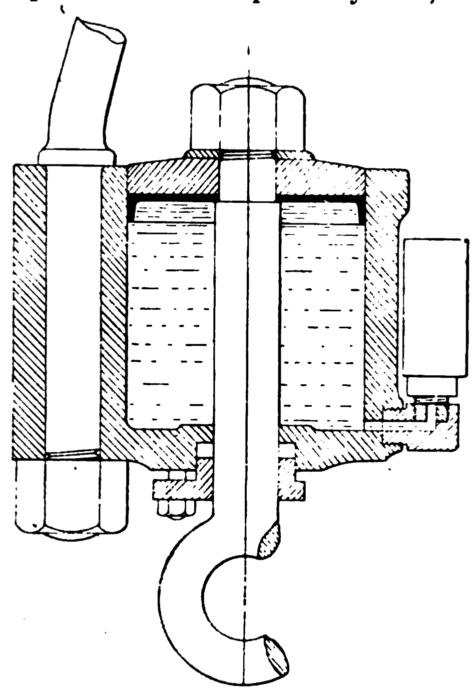


Fig. 221.—"Duckham" Hydrostatic Weighing Machine.

finally draw the curve through the points of intersection.

In Fig. 222 the point L half-way between the foci is called the *centre*. The *transverse* or *minor* axis of the hyperbola is on MN. The lines OP,

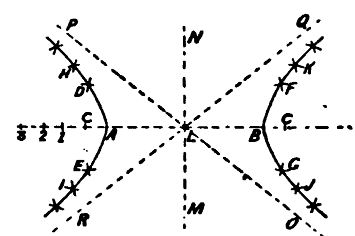


Fig. 222.—Hyperbola.

QR drawn through the centre are the *asymptotes*, and are such that the branches KBJ and HAI of the hyperbola tend continually to approach them, touching them at infinity.

The *Hyperboloid* is a figure derived from the

hyperbola. If a hyperbolic segment, Fig. 222, IAH, or JBK, be revolved about the axis AB, a hyperboloid is generated. The pitch surfaces of skew bevel gears, and spiral gears correspond with hyperboloids of revolution.

Hyperbolic Logarithm.—The common logarithm of a number multiplied by 2·302585.

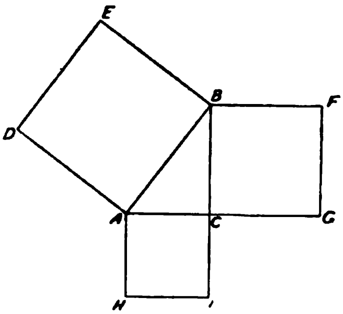


Fig. 223.—Hypotenuse.

Hypotenuse.—Is the side, in a right-angled triangle, which subtends or is opposite to the right angle. The square on the hypotenuse is equal to the sum of the squares on the other two sides (Euclid, 1, 47). In Fig. 223 the square ADEB described on the hypotenuse AB is equal in area to the sum of the areas of the squares BFGC and AHCI.

Hysteresis.—The "Magnetic Inertia" or resistance to magnetisation of iron and steel. Where a magnet is subjected to rapid reversals of the magnetising current—as in the armature core of a dynamo or motor (*see* **Dynamo**)—its molecules are moved with each reversal, and their resistance to movement, dependent upon their density and composition, produces magnetic friction in the mass. This friction causes heating of the iron, and absorbs an amount of magnetising power which is referred to as the "Hysteretic Torque." This explains the fact that hard, dense steel requires more magnetising power than soft iron. In an alternating current magnet, wherein the cyclical changes of magnetic force are very rapid, the iron core gets very hot; this is provided for by building it of fine laminations, and arranging ventilating spaces to allow the heat to be dissipated.

I

I.—Signifies the **Moment of Inertia.**

I-Beam.—*See* **Joist.**

Idler, or **Idle Wheel.**—A wheel inserted in a train simply to change the direction of motion, or to fill a gap. The size of the idler wheel does not affect the velocity ratio.

Ignition Devices.—Ignition devices for gas or oil engines may be divided into four classes. (1.) Those in which a portion of flame outside a cylinder is carried by means of a sliding valve so as to communicate with the combustible mixture inside the cylinder. (2.) Those in which a closed pipe is heated by an external flame, such closed pipe being open to the cylinder, and the combustible gas therein. (3.) Electrical devices in which a pair of sparking points inside the cylinder are so arranged with a make and break device that an electric spark passes through a part of the charge to be ignited. (4.) This, which is an obsolete device, is that of a flame, external to the cylinder, which is momentarily sucked into the cylinder on the rapid opening of a small valve, which is as rapidly closed again. This device was only possible when the pressure in the cylinder was below the atmospheric pressure, and as all such gas engines are now obsolete, the device is no longer employed.

The first class has also fallen into abeyance; it was employed with the early engines of the Otto cycle principle, and served as a means of carrying a flame from a lower to a higher pressure. But the slide valve ignition has fallen into disuse, and the method is obsolete.

Ignition by heat tube is still very much used. The tube is heated at such a point in its length that when the charge in a cylinder is compressed, and a portion of the charge enters the heated tube, it reaches the sufficiently heated length of tube just at the time desired for ignition. Some uncertainty, therefore, attaches to this method, but this is obviated when necessary by means of a timing valve which only admits the compressed charge into the tube at the right moment, the movement of the timing valve being regulated to suit the required period of ignition.

In some forms of oil engine there is an oil vaporiser behind the cylinder, which is maintained hot by the combustion of the charge, and this vessel acts exactly like the heated ignition tube, and serves both to vaporise the oil, and to ignite the vapour, ignition taking place when the piston, on its compression stroke, forces air through the narrow neck attachment of the vaporiser, and permits the vaporised oil to burn.

In the Diesel engine the ignition device differs altogether from that of any other internal combustion engine. The charge in the Diesel engine is pure air. This is compressed to about 500 lb. pressure per square inch, and becomes heated to about 1,000° Fahr. by the act of compression. The fuel charge is injected into this heated air and ignited by it.

In petrol motors the ignition device may be a battery with an induction coil and make and break contact, or it may be simply a magneto machine. An internal combustion engine will often continue to run when the ignition device is put out of action, for it is found that the ignition point, or some projecting nut on the piston, becomes red hot and serves to ignite the combustible charge. A combustible charge, when compressed, will ignite from a point at a lower temperature than the same mixture will ignite at atmospheric pressure. This explains why very poor gases will ignite with certainty when their temperature of combustion in the open is exceedingly low.

I.H.P.—Indicated horse power. *See* **Indicating.**

Impact Tests, or **Drop Tests,** or **Falling Tests.**—These are employed in work which is specially liable to sudden and often repeated live loads of the nature of shocks, the principal

being railway axles, rails, tyres, and cast iron or steel used in crane service. They are invariably supplementary to tensile tests, and are simply a check on brittleness. They vary for the same class of work under different inspecting bodies, and so give rise to some confusion. Impact tests are of most value in the harder steels, containing from 0·2 to 0·5 per cent. and upwards of carbon.

Testing Axles.—English specifications vary. For engine axles they range from 1 ton falling five times in succession through 30 ft., to 1 ton

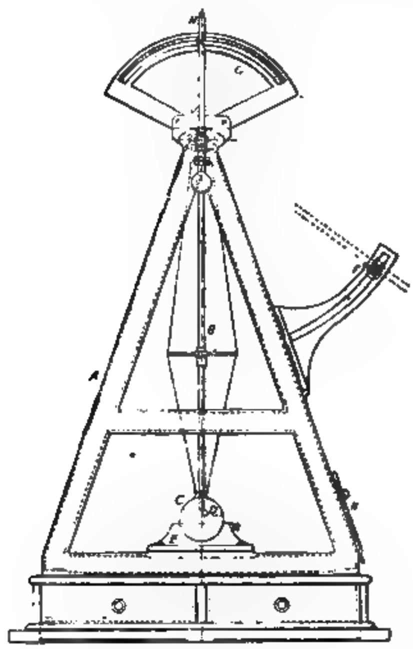
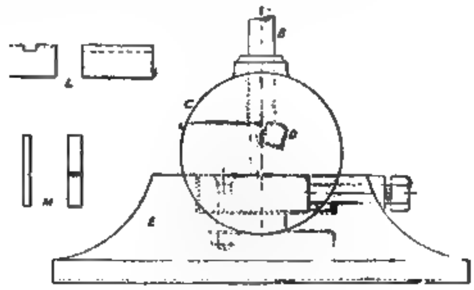


Fig. 224.—Impact Testing Machine. (Messrs W. & T. Avery, Ltd.)

falling sixteen times through 25 ft. The axles are reversed after each blow, or each alternate blow. They rest in bearings 3 ft. 6 in. apart. The amount of deflection at a blow amounts to from $2\frac{1}{2}$ in. to 3 in., the next blow straightening the axle. There must be no sign of fracture, but after the tests the axle is nicked and broken, and samples cut from it for tensile and bending tests. Axles are sometimes deflected to an arc of 90° under the drop weight, and then bent under the hammer until the ends touch.

Rails.—The American drop tests for rails are summarised in the following statements. The drop testing machine has a tup weighing 2,000 lb., the radius of its striking face is 5 in. The range of its drop varies with different rails, from 14 ft. with light rails, of from 50 to 59 lb. per yard, equivalent to a blow of 28,000 foot pounds; to a drop of 18 ft., with rails of from 90 lb. to 100 lb. per yard—equivalent to a blow of 36,000 foot pounds. The supports for the rails are set 3 ft. apart, with a 5-in. radius, and are firmly secured to the anvil block, which is made of ample mass to ensure rigidity. The drop test is made on a



piece of rail from 4 ft. to 6 ft. long, cut at the hot saws from the end of one rail taken from every fifth heat, stamped, and placed on skids to cool. When cool it is placed head upwards on the supports, and must withstand a blow of the 2,000-lb. tup without fracture. A second blow is not required, nor are deflection limits specified. The atmospheric temperature at the time is recorded. In the event of the rail breaking, two additional drop tests are made on pieces cut from two other rails from the same blow. If they fail, all the rails of that blow are rejected, if they stand the test, the blow is accepted.

Tyres.—These are subjected to drop tests in addition usually to tensile tests. The completed tyre being set edgewise, as in service, receives blows of 20 cwt. falling through 10 feet, 15, 20, 25, and 30 feet, until it is deflected one-sixth of its external diameter. The amount of deflection specified is varied with the class of tyre.

Cast Iron.—Impact tests are used for cast-iron test bars in Keep's system, and in general testing. In an appliance which has been used

by the writer the weight is allowed to fall between guides on the test bar, supported on knife edges. The uprights are graduated at different heights. The dimensions, &c., are:—Weight, 12 kilos (26·44 lb.); test bar, 40 mm. (1·57 in.) square, 250 mm. (9·84 in.) long, placed on knife edges 160 mm. (6·29 in.) apart. Fracture takes place between 65 and 90 cm. A good bar breaks at a drop of 70 cm. (27·5 in.).

Izod's patent impact testing machine, Fig. 224, is designed for testing specimens $\frac{3}{8}$ in. wide by $\frac{3}{16}$ in. thick, gripped at one end. A vee notch ·05 in. deep is made across the wider portion. A maximum blow of 23 foot pounds is obtainable. The construction comprises a cast-iron frame A, standing on an oak base, with drawers. At the top of A the pendulum B is suspended on hardened centre points. This pendulum consists of a light steel tube, at the bottom end of which is attached a cast-iron head, C. A blunt hardened steel knife edge D is inserted where the specimen is struck, the position being arranged to be at the centre of percussion of the pendulum. The specimen is gripped in steel dies in the vice E. The pendulum is then lifted to the required height, and secured by the releasing trigger F mounted on the radial arm of the frame, the height being indicated by a graduated quadrant G at the top of the frame, a pointer H moving across the quadrant. On releasing the trigger F the pendulum falls and strikes the specimen, and the indicating pointer engages with a loose weighted finger J, and carries it forward until it shows the amount of energy absorbed by the specimen, on the right hand of the graduated quadrant. After the specimen is fractured, and the pendulum swings back again, its weight may be caught by the hand, and lowered against the rest K, which is moved out to engage, so allowing freedom to examine and remove specimens. Care must be taken that the centre points of the pendulum are set so that it swings with a minimum of friction, without being actually loose. A jig is supplied, shown at L, to enable the specimens M to be cut accurately to size. The enlarged detail to the right hand of the illustration shows the relative positions of pendulum, test piece, and vice.

Impedance.—*See* **Alternating Currents.**

Imperfect Combustion. — *See* **Boiler Efficiency.**

Impermeater.—A vessel which is used for charging the steam for marine engines with greasy matter, for lubrication. Its action depends on the fact that oil being lighter than water will float on the surface of the latter. The impermeater is closed by cocks at top and bottom. The first is for charging with oil, the second is in communication with the steam chest. An internal pipe comes from the bottom cock about half-way up the vessel. When the upper part of the vessel becomes filled with steam it condenses, falling to the bottom, and displacing the oil, which then overflows down the central pipe into the steam chest.

Impulse Wheel.—*See* **Turbines.**

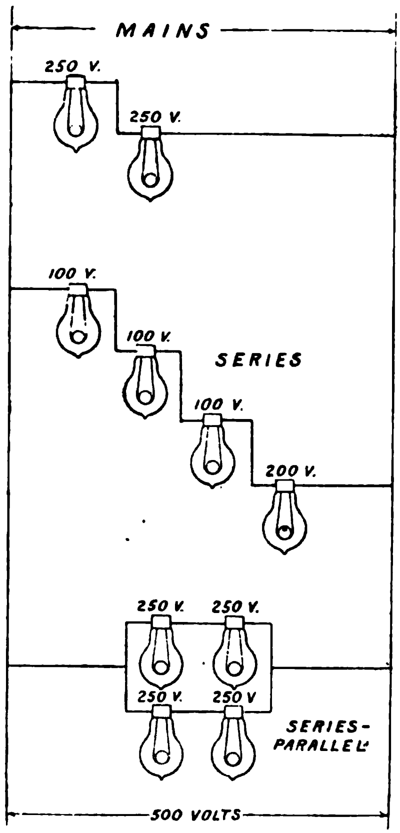
Incandescent Lamps. — *History.* — The first patent for incandescent electric lamps dates back to 1841, in which the use of platinum wire enclosed in a vacuum was described. Carbon filaments were adopted in 1852, and from then on to 1878 not much progress was made; primary batteries being up to that time the only sources of electricity.

But with the production of the first commercially successful dynamo by M. Gramme about that time, the incandescent lamp began to make progress, until lamps fit for use on 100 volt circuits were produced, and processes of manufacture improved by several inventors between 1878 and 1881. The carbon filament was and is retained, but is now invariably made from cellulose, carbonised in manufacture.

Great improvement has been effected in the carbon lamps, chiefly in the direction of increased efficiency and in processes of manufacture. But as even the best modern carbon lamps only give in the form of light 5 per cent. of the energy absorbed—the remainder being wasted as heat—improvement has recently taken the direction of the substitution of other materials than carbon for the filament. Recently placed upon the market, several new incandescent lamps have already made great progress, and of these the electrolytic "Nernst Lamp," the "Tantalum Lamp," and the "Mercury Vapour Lamp," representing the

three directions in which the light-emitting body of glow lamps has evolved—incandescent refractory material, incandescent metal filaments, and incandescent vapours—may be taken as typical of the lines upon which electric incandescent lighting has been developed.

Carbon Lamps.—The carbon lamp consists



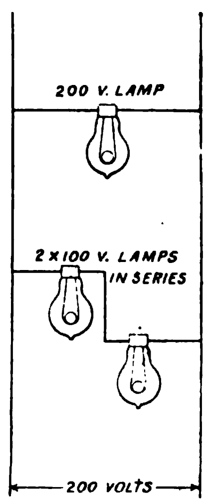


Fig. 225.—Incandescent Lamps.

of a fine thread or filament enclosed in a glass bulb. The bulb having been exhausted of air, is sealed up, and fitted with a suitable metal cap containing the terminal plates to which are attached fine platinum wires, passing into the bulb, and connected to the ends of the filament.

The platinum connecting wires are very short, but it is necessary to use this most expensive material because of the fact that platinum has the same coefficient of expansion as the glass, and therefore preserves the seal at the point of entry to the vacuum bulb. The filament is made from a cellulose solution prepared from gun-cotton dissolved in collodion or acetic acid. This is ejected through graduated jets into an alcohol solution in which it is boiled. After boiling it is washed in clean water, and when dried, has become a strong thread, which is then wound on blocks or formers giving it the required shapes, as horse-shoe, curls, zig-zags, &c. The blocks are placed in pots or boxes, packed with powdered charcoal, and these being placed in furnaces, the filaments are treated at graduated temperatures, working up finally to a temperature of 2,000° Cent. The filaments after this treatment have become carbonised, and are steely-black in colour, hard and flexible.

The filament is next attached to the short platinum wires and the whole placed in the bulb. The end of the bulb is sealed round the platinum by means of a blow-pipe. The bulb is then exhausted by attaching its bottom open end to an air pump, and the filament being at the same time heated to incandescence by passing current through it, a high degree of vacuum is attained, whereupon the end of the bulb is sealed.

The protruding wires are then soldered to their terminal plates, the cap and collar cemented on, and after being tested and calibrated for voltage and candle power, the lamp is ready for use.

Carbon lamps can be manufactured suitable for use on circuits at any voltage up to 250 volts, and for higher pressure circuits may be connected in series. The two methods of connection are shown in Fig 225. Thus on 200 volts, one lamp calibrated for 200 volts may be connected in parallel, or two 100 volt lamps in series; and on 500 volts, two 250 volt lamps in series parallel, or five 100 volt lamps in series may be used, but only lamps

of equal candle power may be connected in *series*.

Every lamp is marked with the voltage for which it is suited, and its candle power at that pressure. Increase of pressure produces extra brilliancy, but shortens the life of lamps considerably, for whilst the filament rapidly disintegrates, particles of carbon are deposited on the glass and the light is obscured. The current consumed by the lamp also increases, until finally the lamp arrives at a state in which whilst it may be taking much more power, it is giving much less light than if run at its proper voltage. Steadiness of pressure is very important in lighting by any form of filament lamp, not only because fluctuation of pressure causes flickering light by variations in incandescence, but also because disintegration of the filament and blackening of the bulb occur sooner on fluctuating pressures. The life of a lamp should not be taken to mean working it until the filament breaks, but rather the time of its actual economical use. This is usually taken at 1,000 hours' burning, but depends altogether upon the conditions of steady and suitable pressure, as well as, of course, the quality of the lamp to commence with. There is no economy whatever in the use of cheap lamps, the best are worth their slight extra cost, which is soon saved by their longer life at good efficiency.

Hours.	16 C.P. Lamp.		32 C.P. Lamp.	
	C.P.	Watts.	C.P.	Watts.
0	16·0	60·2	32·0	115
100	16·6	60·2	33·0	116
200	16·4	61·5	32·5	118
300	15·9	64·0	31·0	121
400	15·4	65·0	30·4	121
500	14·8	65·0	28·7	122
600	14·4	65·0	27·0	122
700	14·0	65·0	26·7	122
800	13·7	64·5	26·0	121
900	13·3	64·5	25·0	121
1,000	13·0	64·0	24·1	121

The foregoing table shows tests of lamps run under voltage conditions of an ordinary municipal supply at 200 volts, and it will be seen that 1,000 hours is the limit of life, having regard to the increase of wattage and decrease of candle power.

The efficiency, *i.e.*, the consumption of electricity for candle power, is in the best English lamps about 2½ watts per candle. The cost of lighting depends, of course, upon the price paid for current.

From public supply mains this may be taken on an average as 4d. per B.T.U.; when, allowing for lamp renewals, the lighting will cost ·21 penny per hour per 16 candle-power lamp. In a works of fair size, and with modern generating plant, however, the power will probably cost, say 0·8d. per unit, when a 16 candle-power lamp and renewals will cost only ·052 penny per hour.

From these figures and those given in regard to areas illuminated for various requirements under **Electric Lighting**, it may easily be found what will be the cost of sufficient lighting for works, offices, &c.

Carbon lamps are made in sizes ranging up to 500 candle power, but the increased use of small arc lamps has superseded the sizes over fifty candle power, above which power the carbon lamps are less economical. One point greatly in favour of the carbon lamp is its adaptability to portable fittings; it can be taken anywhere, and fixed in any position. Being enclosed in glass, there is very little heat given from it, and should the glass be accidentally broken, the light is instantly extinguished. There is thus no danger of fire, in fact, not the least of the advantages of electric lighting is the reduction of fire risk and saving of insurance rates allowed when this system of lighting is adopted.

Incandescent lamps can be used either on continuous, or single or multiphase alternating circuits. With alternating current the best results are obtained with periodicities of sixty to a hundred cycles; if the frequency is low, some flickering of the light may be observed. On the other hand, low frequencies down to twenty-five cycles are preferred for two and three-phase induction motors.

So that in a large works' plant, supposing that alternating current were used for power, if the lighting load, either incandescent or arc,

were large, a rotary converter should be installed for this purpose (*see* **Rotary Converter**), continuous current being more suitable, and the lamps, both arc and incandescent, more efficient and steadier. The fittings, &c., required for the use of incandescent lamps have now reached a high state of perfection, and there are no conditions under which this system of illumination cannot be used with the best results. Other forms of electric incandescent lamps are described under **Nernst Lamp, Tantalum Lamp, Mercury Vapour Lamp,** &c.

Inch.—A lineal measure equal to the twelfth of a foot, or a thirty-sixth of a yard. Ancient statutes enacted that three grains of barley taken from the middle of the ear and well dried should make an inch. 144 square inches = 1 square foot, and 1,728 cubic inches = 1 cubic foot, 39·37079 inches = 1 metre; 1 lineal inch = 25·4 millimetres, 1 square inch = 6·451366 square centimetres, 1 cubic inch = 16·386176 cubic centimetres. *See also* **Miner's Inch, United Inches.**

Inch-pound.—A pound lifted one inch high.

Inclined Plane.—Is one of the six historical "mechanical powers." By its aid the work of raising a weight vertically through a short distance is transformed into the lighter task of drawing it up the plane through a greater distance, but to the same level. No work of course

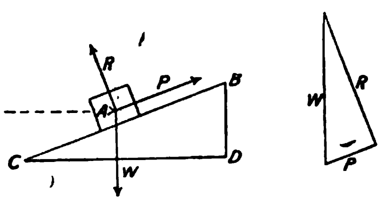


Fig. 226.—Inclined Plane.

is saved, but the exertion of a small force for a long time is substituted for the exertion of a proportionately greater force for a shorter time.

In Fig. 226 the weight A is kept in equilibrium by three forces:—(*a*) the weight W which acts vertically downwards; (*b*) the force P acting parallel to BC; (*c*) the resistance R of the plane acting at right angles to the plane. BC is the length of plane, BD the height, and DC the base. Applying the triangle of forces as shown in the illustration, W : P :: BC : BD, or $\frac{W}{P} = \frac{BC}{BD} = \frac{\text{length}}{\text{height}}$, *i.e.*, the length of the plane is to its height as the weight is to the power. By increasing the length of the plane, and correspondingly decreasing its height, a greater weight can be pulled with less effort, and conversely the steeper and therefore shorter the incline is, the greater the effort needed. As the slope grows less P diminishes, and increases as the inclination increases, but on a smooth plane P is always less than W until 90° is reached. The formula $P = W \times \frac{\text{height of plane}}{\text{length of plane}}$ enables the necessary force to be reckoned. If the weight be 42 cwt. and the slope 5 in 14, then $P = 42 \times \frac{5}{14} = 15$ cwt., the force necessary to support the weight. If the inclination be increased to 10 in 14 then $P = 42 \times \frac{10}{14} = 30$ cwt. The resistance $R = W \times \frac{\text{base of plane}}{\text{length of plane}}$.

In practice, however, the value of P given by this formula would be too small, for all planes are rough, and frictional resistance has to be allowed for.

When the force is applied horizontally (as in the direction of the dotted arrow) instead of along the plane, W : P :: DC : BD, or $\frac{W}{P} = \frac{DC}{BD} = \frac{\text{base}}{\text{height}}$. In this case the formula for estimating the force becomes $P = W \times \frac{\text{height of plane}}{\text{base of plane}}$, and for the resistance $R = W \times \frac{\text{length of plane}}{\text{base of plane}}$.

Inclined Railway.—*See* **Cliff Railways.**

Increasing Pitch.—The pitch of screw propeller blades that increases from the boss towards the tip. The pitch is made finer near the boss, with the object first of lessening the churning of the water there, and partly to give greater strength of hold of the blade on the boss. The increase ranges from about 10 per cent. on large propellers to 15 or 16 per cent. on small ones of coarse pitch.

Increase Twist.—*See* **Twist Drills.**

Incrustation.—The hard scale which lines the waterside of the plates of steam boilers. It is due to the precipitation and hardening of solid matters held in suspension in the water,

and left on the plates by precipitation, or evaporation. Deposits, soft at first, become hardened by heat and form incrustation. The remedy is the treatment of the water previous to use, and frequent blowing off to prevent the accumulation of deposits. Incrustation that does not exceed $\frac{1}{32}$ inch in thickness is not injurious. But over say $\frac{1}{8}$ inch it becomes dangerous, interfering with the transfer of heat, being a bad conductor, and is a fruitful cause of overheating, distortion, collapse of flues, and rupture of shells. Before the thickness becomes excessive it is often removed by a scaling hammer; but prevention should be the object sought.

Independent Crane.—A crane which receives no top support for the post. The term is applicable to fixed cranes only, chiefly of warehouse, wharf, and some hydraulic types, as ingot cranes. An independent crane must have a much larger base than one which has a support to the top of the post. It generally takes the form of a spreading casting, bolted to a suitable foundation, and stable enough to carry the post, jib, and overhang of load.

Independent Jaw Chuck.—*See* **Lathe Chucks.**

Index Centres.—Mechanism for pitching the teeth of milling cutters, plain or spiral gears, or other work for which a large range of equal divisions is required. Index centres are plain, or universal; the term *dividing head* being usually applied to the latter. The centres comprise the head and tail stock on a milling machine bed. They are subject to much variation in design, ranging from very plain hand-dividing types to geared or spiral heads.

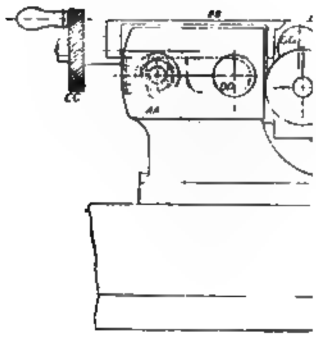
The simpler centres are used for the plain milling of sprocket wheels, straight milling cutters, pinions, and similar work. These have a plate at the rear of the headstock, notched on the periphery to receive a spring catch, or division lever, or drilled on the face with circles of holes. The range of a notched plate is small by comparison with that of a drilled plate. Its special function is the milling of squares, and of sprocket wheels. The drilled plates, or *dials*, contain from four to seven circles of holes, as 24, 30, 36, and 42; or 48, 56, 60, 66, 72; or 44, 48, 56, 60, 72, 84, 96; or 46, 54, 60, 64, 66, 84, &c. The *index peg* or pin is pivoted to reach either

Fig. 227.—Index Centres.

circle. In the smaller index plates the spindle is turned directly, but in the larger sizes a worm gear is fitted. This renders the work easier, and lessens the wear on the pin and holes. The worm can be dropped out of gear when rapid adjustments have to be made.

The fitting of a *spiral head* and index plate in conjunction with a swivelling table and change gears characterises universal milling machines. The index plate divides the circle, and the change gears impart the spiral movement, while the table is being traversed by the feed screw. Though there are general similarities in these heads, yet there are differences in detail in regard to the range of swivel movement and the methods of fitting.

The Brown & Sharpe dividing head is shown in Fig. 227, in elevation and sectional views. A is the spindle, with standard taper, which has a range of adjustment in the vertical plane through the medium of its head B, from 10° below the horizontal to 10° beyond the vertical, graduations giving the angles of setting. It is clamped after adjustment by bolts in its vee fitting. The spindle is rotated at an angle by the worm *a* and wheel *b*. The worm is turned by hand by the crank handle C, or from the feed screw D, through the change gears E. F is the index plate. When the spindle is to be moved by hand, as in cutting coarse divisions, the worm is dropped out of engagement, for which purpose the disengaging motion, the eccentric sleeve fitting *e*, shown in the lower part of the figure, is provided; *e* is an eccentric bushing, having a nut *d*. To throw *a* into or out of gear, turn the knob *c* by means of a pin wrench about a quarter-revolution in the reverse direction to that indicated by an arrow stamped on the knob. This will loosen the nut *d* which holds the eccentric bushing *e*. Then turn both knobs *c* and *f*, when the bushing *e* will be



revolved, and the worm disengaged from the wheel.

When the worm gear is thrown out, the spindle may be rotated independently, being locked by the index plate *g*, and pin *h*, moved by rack *i*, and pinion *j*.

Figs. 228-230 illustrate the head by the Cincinnati Milling Machine Co. The swivelling head A, which carries the spindle B, makes a complete revolution in the vertical direction. The capacity for complete revolution is sometimes an advantage, permitting of the cutting of right and left-hand work without changing the cutter, and of cutting the same piece of work on either side of the perpendicular. Also

the swivel block is contained wholly within its bearings when at any angle. The clamping arrangement holds it securely during cutting without strain on the spindle. This comprises two trunnion bearings on the swivelling block

Fig. 229.—Index Head (Vertical Section).

embraced by the clamping rings C, pinched by two cap screws D. The circumference of the trunnion being large, no disturbing influence can affect the spindle or the worm gear. The edge of the swivelling block is graduated into degrees. The spindle B is provided with a clamp ring at *a* which secures it, and does not disturb its accuracy. The coned bearing neck at the front, and the cone bushing at the back, afford provision for taking up wear. The spindle is hollow, with a tapered hole.

The dividing mechanisms include the worm and wheel and a special index plate E. The latter is used for low numbers, in order to avoid the risk of mistakes in counting the number of turns of the worm. Divisions under forty are effected with this plate. On all divisions of forty and over more than one turn of the worm is not required. The plate E for direct indexing is dish-shaped, and has three circles of holes, 24, 30, and 36, on the back, where they are protected from dust and chips. The use of this plate saves time, and avoids risk of error due to counting the turns of the worm, which in this case is disconnected when the cup-shaped index is used. The pin holes for four and for six divisions, which are frequently required for fluting, nut making, &c., have their positions indicated on the edge by figures 4 and 6, so saving the trouble of counting the holes. This plate has a further utility in the fact that when in a position approaching the vertical it affords protection to the cutting head against chips and oil.

The worm G and its wheel H are seen in gear in Figs. 229 and 230. The worm is disconnected by being dropped bodily in its bearing or case J. The latter has a vertical movement only, which is effected by the eccentric pin K that moves the case bodily up or down. As the latter is confined sideways, the eccentric end of the pin is inserted in a bushing or pin L, which has endlong motion in the worm case.

The screws M tie the worm case to the block above, which is drilled for L, and by means of these screws the worm is adjusted to the wheel in a straight line. At the other end the worm case swivels about the pin N as a centre. Thus two separate adjustments are provided, and each in a straight line, that for taking up wear by the screws M, and that for engagement and disengagement by the lever K and sliding pin L, which are ideal arrangements theoretically correct.

Fig. 230.—Index Head (Transverse Section).

The worm is single threaded, right handed, with two and a half threads per inch. It runs in an oil bath supplied through the tube O. The cap P can be removed for the purpose of cleaning and examination. The wheel has

forty teeth, so that forty turns of the handle R move it through one revolution. Both it and the index plate are of good size. The index plate Q is drilled from both sides, so that when reversed it provides a large number of divisions without extra plates. Extra special plates are provided for effecting divisions that cannot be obtained directly from the standard plates furnished with a machine. Such divisions have hitherto been obtained by the tedious method of compound indexing.

The dividing or indexing head is used on plain machines as on universals, but the change gears for spiral work, only upon the latter. The illustrations, Figs. 228 and 230, render this mechanism clear. In Fig. 230 the revolution of the handle or index pointer R turns the worm and its wheel through equal gears, S, T. When spirals are being cut, the worm is driven through the gear U. The connecting up of change wheels is illustrated in Fig. 228 from the lead screw V. W is the swing plate, X, X the two studs for compounding trains. The motion is transmitted to the spindle at right angles by the bevel wheels Y, actuating the spur wheels in Fig. 230, the dotted outlines of which are seen in Fig. 228.

The Tailstock or Footstock.—This is used for work which has to be supported at both ends, as in fluting drills and reamers, long pinions, or rows of sprockets. Invariably the top of the plunger or mandrel is flattened to permit of cutters being operated close to the centre. Also, for cutting tapered reamers, provision is made for elevating or depressing the centre. A footstock by the Cincinnati Milling Machine Company is seen in Fig. 228. The housing AA carries the longitudinal slide BB, which fits into it with a dovetail, being traversed by the knob CC, and clamped by the bolt DD. The centre bar EE is double-ended, one end having an ordinary centre for heavy work, the other being reduced on the top face to permit of the milling of small work. The position of the bar is readily reversed. It is adjustable vertically with rack and pinion actuated by the knob FF, and clamped by the bolt GG. The centres can also be tilted forward, swivelling about the centre DD, graduations on the housing giving exact angles.

A style of plain centres by the same firm, used where it is not necessary to cut bevel or

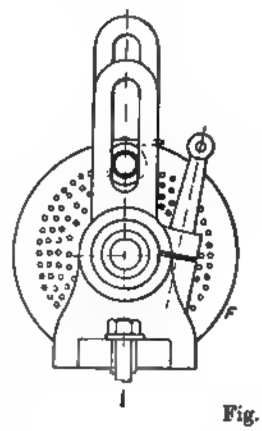


Fig. 231.—Plain Index Centres.

spiral gears, is shown in Fig. 231. The spindle A is supported in bearings B and C, and the nut D is screwed to fit the body, so that turning the nut by the fingers causes the spindle to be drawn either backwards or forwards, to tighten on or release the work. This provision is made because the footstock employed has not the usual power of endlong adjustment. The small screw *a* presses on the spindle, and causes enough friction to prevent the nut D from turning accidentally, and to move it with the motion of the index plate. The centre E fits in a taper hole in the spindle, from which it may be ejected by a rod from the rear. The index plate F, of which two or more may be supplied, is locked by the spring plunger or pin G, the latter being adjustable up and down the slotted

standard on top of bearing B. Graduations on the edge of the standard indicate the exact position of G for the different circles of holes. After the spindle A is set in position, it is clamped firmly by the handle, closing in the split bearing E.

Indexing.—Signifies the obtaining exact divisions of the circle for fluting and milling by means of the divisions on the dividing or *Index head* (*see* **Index Centres**), with its feed

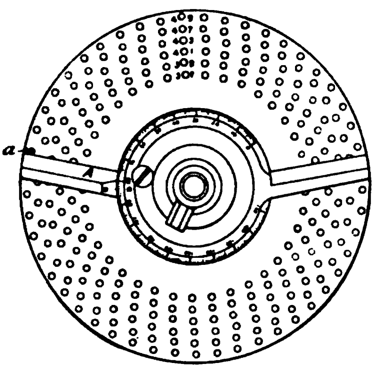


Fig. 232.—Index Plate.

screw and change gears. The index plate gives equal divisions, the change gears impart a rotary motion to the spindle, the amount of which is related to the pitch of the lead screw, thus:—The worm wheel has forty teeth, and the worm is single threaded, therefore one turn of the *index crank* or worm shaft produces one-fortieth of a revolution of the spiral spindle.

The worm thread and wheel teeth being as one to forty, forty revolutions of the wheel to one of the worm form the basis of calculation. The value of the index plate lies in making subdivisions when the crank, or pointer, has to make less than a complete revolution to effect the required divisions. Forty turns of the crank effect one revolution of the main spindle, and as one turn would effect a fortieth of a revolution of the main spindle, therefore this operation would have to be repeated forty times to obtain forty divisions to the circle. To obtain eighty divisions the crank would be turned but half-way round for each division; to obtain twenty, two turns would be required. Hence the rule:—Divide forty by the number of divisions required, and the quotient will be the number of turns or parts of a turn which will have to be imparted to the crank. Thus:—

$$\frac{40}{40}=1. \qquad \frac{40}{20}=2. \qquad \frac{40}{80}=\cdot 5.$$

Or, taking say 144; then $\frac{40}{144}$ may be reduced to $\frac{5}{18}$, which means that the crank must be moved $\frac{5}{18}$ of a turn.

In these fractional parts it is necessary to select circles of holes which are either of the number required, or a multiple of the same, as 18, 36, 54, 72, &c. Here the value of the sector comes in. The counting of holes is liable to error, but having a sector once set, say to every fifth hole in the 18-hole circle, or tenth hole in a 36 circle, all further risk and trouble are saved. The sector, it must be noted, is set to one hole more than the spaces to be counted, and there clamped. In other words the hole in which the index pointer is put is not counted, but the 5, or 10 holes, or other numbers as may be required, are counted from this one, *a*, Fig. 232, into which the index pin is thrust. After the sector has been tightened no further counting is necessary, but the sector is simply moved against the index pointer at each time of division. When this has been repeated the proper number of times, and a cut made at each setting, the main spindle in

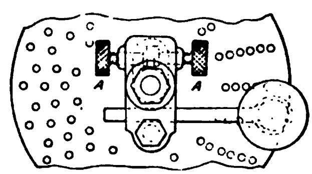


Fig. 233.—Adjustable Index Crank.

the dividing head will have made one revolution. To facilitate this work and save the labour and risk of calculation, index tables are furnished which give opposite the number of divisions required, the number of holes in the index plate which should be selected; and the number of turns of the crank required for the circle of holes chosen. These tables may also be used merely as a basis to work upon, since other

circles and numbers of turns can be readily deduced therefrom.

Fig. 233 illustrates a device by Brown & Sharpe, when the index pin will not drop into a hole at a definite start of the work. The index crank is adjustable by the screws A, A.

The division plates alone are necessary when fluting taps and reamers, and in cutting spur wheel teeth and ratchet teeth. But for spiral teeth, twist drills, spiral reamers, and spiral milling cutters, the spindle must be rotated by the change gears. These are like those used for screw cutting in the lathe, but calculations are rather different. Instead of taking the pitch or number of threads per inch of the screw as the basis, the distance through which the table travels during one revolution of the spindle in the dividing head is given, and this is termed the *lead of the spiral*. If the spindle makes one turn to 6 inches travel of the table, the lead is 6 inches; if one turn in 10 inches, this is a lead of 10 inches. The calculations are simple because the lead screw usually has four threads per inch, and forty revolutions of the worm, as already stated, are required, to impart one revolution to the spindle of the dividing head. If gears of equal diameter were put on the lead screw and on the worm shaft, the lead screw would have to be revolved forty times to turn the worm shaft forty times, and in that period the table would travel 40 divided by $4 = 10$ inches. Other gears are obtained by multiplying the required lead in inches by four. Hence the ratio :—

$$\frac{\text{Number of teeth in driven gears}}{\text{Number of teeth in driving gears}} \text{ must equal } \frac{4 \text{ times the lead}}{40}.$$

Having obtained the ratio in the form of a fraction, the latter is divided into two factors as in screw cutting, and the numerator and the denominator of these fractions are multiplied by a convenient number to give numbers of teeth in wheels in the set available. This applies to compound gears. Thus, to cut a spiral with a lead of $10\frac{1}{2}$ in. :—$10\frac{1}{2} \times 4 = 42$. The lead screw must make 42 turns to 40 turns of the worm. The ratio is $\frac{42}{40}$.

Then $$\frac{42}{40} = \frac{7 \times 6}{8 \times 5}.$$

Multiply, say, by $8 = \frac{7}{8} \times \frac{6}{5} \times 8 = \frac{56 \times 48}{64 \times 40}$, and 64 and 40 are the driving gears, and 56 and 48 the driven. Either 64 or 40 may be put on the lead screw, the other going on the first intermediate. Either 56 or 48 may go on the worm shaft, the other going on the second intermediate.

In a simple train, two wheels give the ratio, one going on the worm shaft, the other on the lead screw, with an intermediate, which of course may be of any size to connect them.

The setting of the table to the angle of the spiral of the cut is obtained either graphically, or by the aid of tables. In the first case the hypotenuse of a triangle is taken, one side of which equals the lead, the other the circumference of the spiral. In the second case the circumference is divided by the lead, and the quotient compared with a table of natural tangents, and the table set to the degrees obtained. Or a table is consulted which gives a wide range of angles for different spirals.

Compound Indexing.—This is a system adopted when divisions are required which cannot be obtained by direct indexing with the index plates. It involves taking either the sum, or the difference of two separate indexings on two circles. The movement of two indexings in one direction is indicated by the + sign, that of two indexings in opposite directions by the − sign. It involves the addition and subtraction of fractions, the denominators of which indicate the circles of holes in the index plates that are selected for use.

Differential Indexing.—This is a simpler method than the compound. The principle is, that instead of locking the index plate with a stop pin, the plate is geared to the spindle, thus allowing the indexing to be made with one circle of holes, and the index crank turned in one direction only, as in simple indexing. Forty revolutions of the index crank being required to make one revolution of the index spindle; if, therefore, the index plate is geared to the spindle, using an idler to give one turn in the same direction as the crank, and the crank pin

enters the same index hole, the result wll be the spacing number 39; because, while the crank has made 40 turns, and the plate one turn in the same direction, the crank has passed a given point only 39 times. Using the same gear, but with the addition of another idler, the motion of the index plate is in the opposite direction to that of the crank, and the plate gains one revolution on the crank, making the spacing number 41. With the spacing number 39, divisions can be obtained equal to 3 by 39 with a circle of three holes; of 4 by 39 with a circle of four holes, &c. The same remark applies to the spacing number 41. Hence any division not obtainable with the index plate can be made up with proper gearing. The general rule, therefore, is:—If the plate rotates in the same direction as the crank, subtract the turns of the plate to one turn of the spindle, from the turns of the crank to one turn of the spindle, and the remainder is the spacing number. If the plate rotates in the opposite direction to the crank, the spacing number will be the sum of the turns of the plate to one turn of the spindle, added to the turns of the crank to one turn of the spindle.

Indian Steel.—*See* **Wootz.**

Indiarubber, or **Caoutchouc.** — Is the milky juice of various orders of trees (Artocarpaceæ, Euphorbiaceæ, and Apocynaceæ), which flourish in tropical climates. The principal sources are the forests of Brazil, Africa, Central America, and the East and West Indies. About 1770 (thirty-five years after its introduction into Europe), it was sold at 3s. per cubic half inch for rubbing out pencil marks. Hence its name. Later, Mackintosh applied it to the waterproofing of cloth, and about the middle of the last century the introduction of the process of vulcanising gave a great impetus to the use of rubber. For many years the demand has been greater than the supply. Explorers have sought new sources of rubber supply, and at home, manufacturers have attempted to produce satisfactory substitutes, but so far without success.

Raw rubber is collected by making incisions in the trunk of the tree, and attaching cups beneath, so that the milky juice oozes out and fills the cup, hardening on exposure to air. Dirt and impurities are separated by boiling the rubber and passing it between rollers. The properties possessed by crude rubber are magnified by vulcanising it. Elasticity is greatly increased, heat and cold no longer affect it, oils are unable to destroy it, nor may it be readily dissolved like pure rubber by turpentine and naphtha. Vulcanised rubber is made by mixing sulphur with the pure article and heating to high temperatures, the maximum temperature depending on the proportion of sulphur and the class of product desired. The details of the process vary widely—the sulphur may be applied ground, or in solution as bisulphide of carbon, and such constituents may be added as lamp-black, antimony sulphide, chalk, zinc oxide, lead thiosulphate, tar, old rubber, asphalt, lime, resin, or whiting. Some of these are used to colour the rubber red, black, or white, others to give it special properties, and others are mere adulterants. In the manufacture of machinery belting French chalk is largely used to make it non-adhesive. Belting and tubing are also made of alternate layers of rubber and canvas.

From 3 per cent. to 10 per cent. of sulphur is used in vulcanising rubber, but if the proportion be increased to 30 per cent. and the temperature raised to 300° Fahr. the substance produced no longer resembles rubber. It is a black, hard, horn-like substance, capable of taking a high polish, and is a non-conductor of electricity. This substance goes under the name of ebonite or vulcanite.

Indicating.—A steam engine has its gross power ascertained or "indicated" by means of an **Indicator**. When an indicator diagram is to be taken, the diagram paper is tightly encircled on the paper drum, the indicator being in working order, and hot from having made a few strokes under steam; this is shut off by the cock, and in this neutral position, which allows atmospheric pressure on each side of the piston, the pencil is pressed against the paper, and the atmospheric pressure line is drawn. The steam tap is then opened, and the now moving pencil is allowed to travel on the paper for a period of one to a dozen turns of the engine, as required by circumstances. The figure

thus obtained is divided into any number of divisions by vertical lines, and the breadth of the diagram is measured by the correct scale at the exact middle of each division. Ten is a usual number of divisions, in which case the sum of the breadths at the ten divisions when divided by ten will give the mean breadth of the figure, and therefore the mean pressure acting on the face of the piston at that end of the cylinder. If, now, the mean pressure per square inch be multiplied by the area of the piston in square inches, the product will be the total pressure on that face of the piston. The distance travelled by the piston in one minute is the product of the number of strokes by the length in feet, and the product of this and the total load will give the foot pounds of work done per minute. Divided by 33,000, the indicated horse power is obtained. The total indicated horse power must of course be found by means of a diagram from each working face of the piston. For rough approximation one diagram is assumed to be the same as that for the opposite face, but for accurate work each end is indicated separately, an allowance is made for the area of the piston rod, and tail rod if any, and the indicator is tested by weights as a check on the accuracy of the springs. The indicator diagram serves many useful ends in addition to that of power determination. From it may be determined the correct adjustment of the distribution valves, the ratio of the pressure in the cylinder to the boiler pressure; the tightness of the valves and of the piston may be judged from it, and also the effects of cylinder condensation. But all these matters cannot be determined except by an expert steam engineer who knows how to balance cause, effect, and probability, and he should, for best results, not merely know the engine, but should have taken the diagrams himself.

As a general aid to comparison it is usual to draw upon the diagram the rectangular hyperbola, as delineated from a line which represents the proportion of clearance in the cylinder, and the line of absolute vacuum. By means of this hyperbolic curve of expansion the curve of the diagram is easier to judge. For engines of high rotative speed the rotation of the paper drum is rapid and demands a small drum of small inertia. The height of the diagram must also be kept small by using a strong spring on the instrument. By means of an Amstler planimeter with points on the radius bar which can be set to the length of the diagram the mean pressure of a diagram can be very quickly and accurately determined.

When indicating gas engines or oil engines the high initial pressure renders desirable indicators with pistons of very much less diameter than are used on ordinary work.

The indicating of engines driving an electric tramway of few cars is useless as a means of ascertaining the mean load, for the variation in load is too rapid to allow of any reasonable probability of finding a mean from so many diagrams. In such a case the pencil may be allowed to run round for several minutes, when the maximum and minimum load may be found, the general diagram being a broad black band of pencil marks, on which an approximate mean diagram may be roughly drawn through the apparent average of the colour band.

Indicator diagrams are taken also from the condensers of steam engines and from the delivery side of the air pump between the bucket and the delivery valve, and from any vessel containing vapour or liquid under pressure where it is desired to know what is the intensity of such pressure relative to the movement of some part, such as a piston.

For the measurement of numerous diagrams the Amstler planimeter is a great help. The best form is that which has two points on the integrating wheel slide and on the bar. When these points are set to the length of the diagram the reading of the wheel gives the mean height of the diagram or, with proper scale, the mean pressure.

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Indicator.—In a cotton mill, an indicator is simply a piece of clockwork with a dial face, so connected with the front roller of a slubbing or roving frame as to indicate on the face the number of hanks, of 840 yards, that the machine has produced. By this indicator the attendant is paid. An indicator, in a colliery winding plant, is a dial with a moving finger so connected to the winding engine as to indicate the distance of the cage from the top or bottom of the shaft. It serves as a check on overwinding.

Indicator—Steam Engine.—The steam engine indicator is an instrument by which the pressure of steam in the cylinder of an engine is recorded on a paper drum at each part of the stroke of the engine piston. In its simplest form, suitable for slowly moving engines and low pressures, a brass cylinder containing a piston is attached to the engine cylinder, and is in communication below the indicator piston with the cylinder steam space. The indicator cylinder contains a loosely fitting, but steam grooved piston, attached to a spring and rod which carries a pencil, the point of which is lightly pressed against a sheet of paper wrapped round a drum which rotates to and fro uniformly with the to and fro stroke of the engine piston. The paper drum surrounds and encloses the cylinder of the indicator. The Hopkinson and M'Naught indicators were of this form, but are practically obsolete. More modern indicators have a shorter and stiffer spring attached to a system of light levers which carry a metal point, the levers multiplying the piston movement several-fold. The paper drum is quite separate from the steam cylinder, and the paper is "metallic."

The Richards indicator is the oldest form of this lever movement instrument, its levers being a Watt parallel motion, the pencil socket being the guided point.

Newer forms are the Thomson, Tabor, Dobbie-M'Innes, and Crosby; while the Darke indicator guides its pencil by a slot in a vertical plate, the pencil being carried in a crosshead which slides on a lever moved by the piston.

In Kenyon's indicator the spring is a Bourdon tube, the moving end of which actuates the pencil.

The Simplex indicator has an external spring consisting of two flat arms, connected by a short piece, in the form of a letter U. The ends of the legs are formed into long cylinders and slip sideways into sockets in the head of the piston rod, and the framing of the instrument. This is an instrument very convenient to use; the springs can be changed rapidly without necessitating anything being moved or unscrewed.

Indicators are best attached to engines by the shortest pipes possible so as to ensure freedom from water, and a true reading. The paper drum must be driven from the engine so that its angular rotation exactly corresponds with the crosshead movement. Slight incorrectness of movement is given by most methods of connecting and driving the drum. These various errors will be found described in some of the little treatises on the instrument.

Special indicators are made for special pur-

poses, one, for example, having the paper drums double, and so arranged that numerous diagrams in succession can be taken on a long band of paper which is wound from drum to drum a few inches at each taking of a diagram. For high pressures, indicators with pistons about $\frac{3}{8}$ in. in diameter instead of, as usually, about $\frac{3}{4}$ in. are used, so as to avoid stress and excessive weight of springs, &c.

There is a great difference between the handiness of different instruments. There ought to be an easily applied detent which will hold the drum of the indicator at rest without the necessity of uncoupling the driving cord. Some instruments have this detent.

One of the best driving cords is a brass wire braided with hard linen, the brass being inelastic, and the linen keeping it visible and easier to handle.

For gas engines the indicator may be fitted with a pad or sieve of wire gauze to stop possible grit from getting to the piston.

Even if the pressure at all points of a steam turbine could be ascertained by the indicator, the information would be valueless as a means of finding the power of the turbine. This is ascertained by means of a novel sort of indicator, the spring of which is a length of the shaft of the turbine itself. Under the turning moment of the turbine the shaft undergoes a certain small angular torsion which can be multiplied by levers and measured. What each degree of arc of twist in a given length represents may easily be ascertained by the simple process of holding the shaft still, and loading it with a known weight on a given lever arm. This is perhaps more strictly to be termed a dynamometer than an indicator, for it does not measure a fluid pressure, and the steam engine indicator strictly speaking is simply an instrument that measures the pressure in a steam engine cylinder at every portion of the stroke. We may thus include the mean pressure instrument of Ripper. This is simply a pressure gauge connected to the cylinder by passages which are so much throttled that the instrument stands practically steady, and shows the mean pressure in that cylinder on a time basis.

It is necessary to correct the mean pressure thus found to a basis of piston movement, for the piston does not generate equal volumes in equal times, and the mean pressure shown by the instrument is not, therefore, the mean pressure to be calculated as producing work.

It is usual to advise the use of the best light oil for an indicator. This is right for the various pin joints, but for the piston it is desirable to use the best thick cylinder oil or valve oil, for this becomes sufficiently liquid when hot; and there ought to be provided an opening by which fresh oil can be introduced below the indicator piston without removing this. This is especially desirable when a long series of diagrams is to be taken on a test of considerable duration.

So far as the writer knows, no indicator has yet been made in which use is made of the corrugated plate, as adopted in the aneroid barometer, or the Schaffer gauge. Such a disc may have a very slight movement to be multiplied by levers.

Continuous indicators are made which are really integrating instruments. A few forms may be named. In the first, Ashton's, the piston rod of the indicator carried a little wheel, the edge of which at rest, or pressure = 0, stood exactly at the centre of an oscillating disc driven from the engine crosshead. According to its position on the face of the disc the little wheel made more or fewer turns, and these were communicated by gearing to a train of wheels like a gas meter index, and the power generated could be read off at any time. The fault of this instrument was that the rotating disc wore most rapidly nearest to its centre, and the wheel ceased to make good contact.

In Vernon Boy's instrument a small wheel was drawn to and fro along a brass cylinder, or rather the cylinder was drawn under the wheel, which was held at various angles to the cylinder axis by the varying pressure in the engine cylinder. The brass cylinder had thus rotated a small amount at each traverse, and this was transferred by gears and an index, as in the Ashton instrument.

In the second instrument of W. Ashton, a small roller was rolled by the action of the indicator piston upon the surface of a brass hyperboloid set in a frame at a slope, so that the curved face of the hyperboloid was as nearly

as possible suited to the movement of the roller, which had, however, a provision that caused it to press uniformly on the hyperboloid. The hyperboloid was drawn to and fro along the roller by an attachment to the engine crosshead. Thus the rotation of the hyperboloid depended upon the position of the roller on its face, and this was determined by the steam pressure. On the spindle of the hyperboloid there was a worm of large diameter and of very small pitch, so that when the roller was at the position corresponding to pressure = 0, the amount of rotation of the hyperboloid as it was drawn to and fro was such that the rotation of the fine pitched worm was timed to cause this to run in gear with a long fluted roller, the teeth of which were slightly inclined upon its surface. Thus this fluted roller did not rotate. But if the indicator roller were at any other position on the hyperboloid, then this rotated differently, and the fluted roller was driven round one way or the other by the worm disc, and the amount of rotation was communicated to the indexes, as in other instruments.

In Little's instrument, an integrating wheel is turned by its contact at various angles with a rotated cylinder, driven from the crosshead of the engine, and the rotation of the integrating wheel is recorded. None of these instruments have come largely into use, but the hyperboloidal instrument of Ashton, utilising large movements, seems to possess features rendering it suitable for regular practical use, and probably a modification of the instrument using a Bourdon spring as the means of measuring the steam pressure would serve to record the power of, say, a large marine engine on a voyage of many thousands of miles. Instruments with pistons are apt to become leaky with long regular use.

Indicators for Machine Tools.—The indicator employed for testing the truth of machine tools, and the location of work placed thereon, is a type of magnifying device by which small amounts of error are increased by the instrument and rendered plainly visible. The construction is that of pivoted levers, one or more in number, which in a cumulative manner ultimately show a movement much exaggerated on a scale or dial. The relations between the first point, or feeler, and the indicating pointer being known, the graduations on the scale therefore show how much movement of the feeler has actually taken place. It would be difficult, if not impossible in some cases, to detect minute amounts of variation in the running of a spindle, or the motion of a plane surface in relation to another, without the use of an indicator. The micrometer is applicable in some cases, but its unyielding character bars it for much work, whereas the indicator feeler accommodates itself to any irregularity, and is not damaged by pressure.

A simple type of indicator, Fig. 1, A, the Brown & Sharpe, comprises a cast-iron base *a*, of girder form, to which a pillar is attached in any position by means of a nut. An arm *c* is clamped to this pillar, in scribing block fashion, and may be moved up or down, and swivelled around, and then fixed with the small handle. Lying within *c*, and pivoted near to one end, is the pointer *d*, one end of which is a feeler, the other an indicator, passing over the scale of graduations on the frame *c*. The small screw *e* serves to tilt the point to zero position when desired. The instrument indicates to 1,000th of an inch of movement.

The Starrett instrument, Fig. 1, B, is mounted on a base and pillar, and the pivoted pointer also passes over a quadrant scale. A spring *a*, fastened close to the pivot, keeps the pointer pressed up at the end of the scale until pushed away by the work. Either the end or the underside of the pointer may be used.

In the Bath indicator a more compact arrangement is secured by using a combination of three levers contained within a case. The instrument C, Fig. 1, has a shank *a*, held by a pivot to the case *b*, the cover of which is shown removed to expose the interior. A feeler *c*, screwed through a hole in the case into a pivoted block *d* causes the latter to move a long lever *e*, and through that another *f*, the end of which traverses graduations on the top of the case. The spring *g* keeps the parts normally at zero. Should the motion of the feeler *c* be too much for the range of the levers, the whole case tilts back on the pivot of *a*, and no damage is done. Several kinds of feelers are employed for various work, including holes and outside diameters. There are two holes in the block *d*. If the

feeler is screwed into the lower hole a motion of 1,000th of an inch will show $\frac{1}{12}$ in. on the scale, if into the upper hole the same movement will register $\frac{1}{6}$ in. Very minute movements are, of course, noticeable. A fitting supplied with the tool comprises a short spindle, pointed at one end, and containing a plunger within the other, pressed outwards by a coiled spring. It is used for setting work true in the lathe by its centre hole, the fitting having its point inserted in the work, and its plunger resting against the poppet centre. The indicator is then applied to the outside, and if it runs true the centre hole in the work must necessarily be true also.

A form of indicator recently introduced has a circular dial of compact form, with a plunger projecting, the motion of the latter being greatly magnified by toothed wheels, and indicated by a pointer revolving around the dial.

These indicators are used to test running spindles, simple contact showing whether any eccentricity is present; to set work true in the lathe or grinder; to test the truth of running holes; the accuracy or parallelism of rectilinear movements, as in planers and milling machines, any divergence from parallelism becoming apparent on watching the indicator pointer.

The centre tester is a type of indicator especially useful for locating a piece of work centrally on the face plate or chuck. It has a holding bar, *a*, Fig. 1, D, to which it is attached by means of a vertical universal joint, enabling the pointer *b* to tilt in any direction. By holding the bar *a* in the slide rest, and placing the pointer at right angles, so that its pointed end enters the hole in the work, any divergence from concentric running will be shown by the wobbling of the other end of the pointer. The latter is frequently drawn down finely at this end also, so that it may be placed against the poppet centre, to see whether it coincides therewith. The instrument can also be used as an ordinary indicator on outside and inside work, but it has no scale to read by, though this does not matter for some classes of testing.

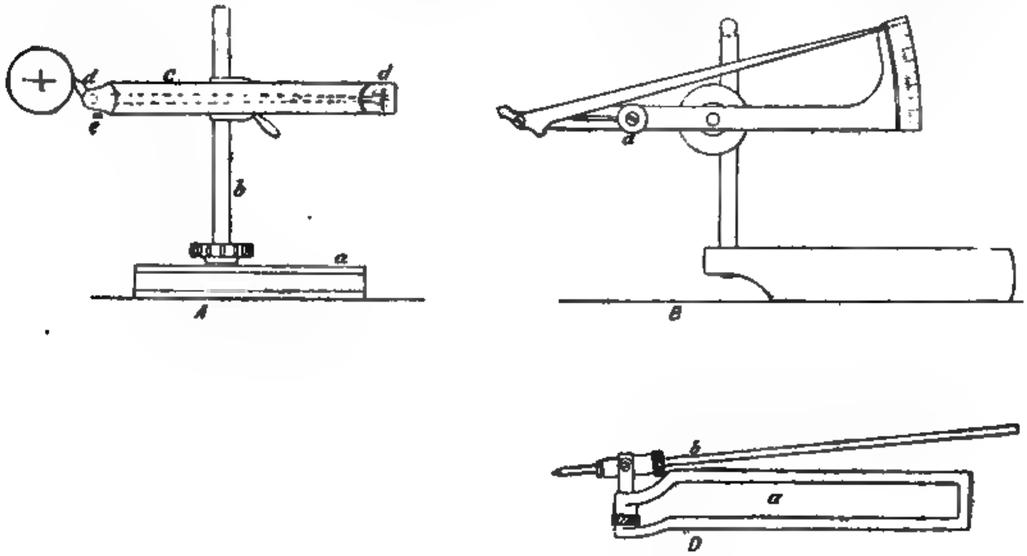


Fig. 1.—Indicators for Machine Tools.

Indicator Diagram.—A diagram, Fig. 2, drawn on a card (or paper) revolved on a drum by the pencil of an indicator piston. *See* **Indicating.** In Fig. 2 the point A corresponds with the point at which steam is admitted to the cylinder—the *admission corner*. The admission takes place as indicated from A to B—the *admission line*, and this line should be approximately vertical. The pressure continuing constant during the period of admission,

the line B to C is marked, which should be approximately horizontal. From C to D the steam supply is being cut off, and works expansively from D to E, when the exhaust is opened, and remains open from F to G. It is closed at G, and cushioning takes place from G to A when steam is again admitted. F G is therefore the *atmospheric line* in a high pressure engine.

When a planimeter is not available for the measurement of diagrams, the best method

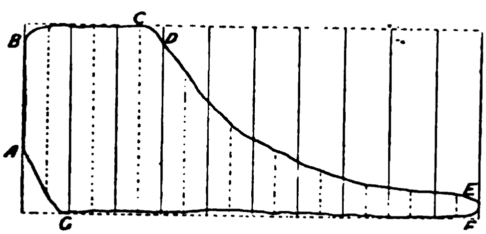


Fig. 2.—Indicator Diagram.

of calculating is to employ a ruled paper with as many rulings as the scale of the indicator spring, in parts of an inch. Thus a $\frac{1}{30}$-in. spring would need a paper with thirty spaces, the end two being of half the breadth of the others. The diagrams are ruled at each end normal to the atmospheric line, and divided at thirty points in this case by laying the ruled paper at the necessary angle to extend exactly between the end perpendiculars. Where each line comes to the edge of the paper the diagram is marked and thirty parallel lines drawn across the diagram. Then with a long strip of paper the diagram breadths at each division are marked in succession along the strip. The total length on the strip measured in inches is then the mean pressure of the diagram. Once a set of ruled sheets has been made they will last indefinitely, and for springs of, say, $\frac{1}{20}$, $\frac{1}{40}$, $\frac{1}{60}$, $\frac{1}{80}$, $\frac{1}{120}$, only five such cards are needed. For the higher numbers the rulings may be fewer. Thus the $\frac{1}{120}$ spring may have forty rulings, and the final length on the narrow strip will give then one-third the mean pressure. It is much more accurate to take the sum of the breadths of a diagram by actual measurement on a strip than to attempt to give each breadth a definite figure, and add up these to a total. With the paper strip and a sharp pencil the additions may be very accurately made. If diagrams are cut out by a pair of scissors and weighed on a chemical balance their weight may be compared with that of a few carefully cut rectangles of the same paper of known area and the mean area of the figures obtained. This is only of use where each diagram is of exactly equal length. Otherwise the mean breadth cannot be found.

Indifferent Equilibrium.—*See* **Equilibrium.**

Indirect Processes.—The processes by which the largest amount of malleable iron is manufactured. They include the puddling methods—the principal; the open-hearth, and the Lancashire hearth. In these, pig is first obtained, while in direct processes ore is treated. The pig is then decarbonised, with or without preliminary refining.

Induced Draught.—The advantages of artificial draught over the natural draught of a chimney have been stated in the article **Forced Draught**, and they apply to the induced systems. The difference lies in the method of producing the draught, and the considerations why preference is given to one over the other.

Induced draught is produced by placing an exhausting fan in the base of the funnel or chimney. The Ellis & Eaves' patent system of induced draught, as illustrated in Fig. 3, includes an apparatus for heating the air for combustion by the waste gases from the furnace. There is a double advantage in this, because the waste gases are cooled sufficiently to prevent their causing injury to the fan. There are therefore three sources of gain, mechanical draught, heated air, and utilisation of waste heat.

The system possesses the following features. As the gases pass from the smoke box they enter the *air heaters* or hot air *economisers*, and thence go to the fans, which discharge them into the funnel. The heated air then enters the furnaces through regulating valves. The air heaters are boxes containing a number of short vertical tubes through which the products of combustion pass, and around which the air to be heated circulates. The air to be heated is drawn into the boxes through open-

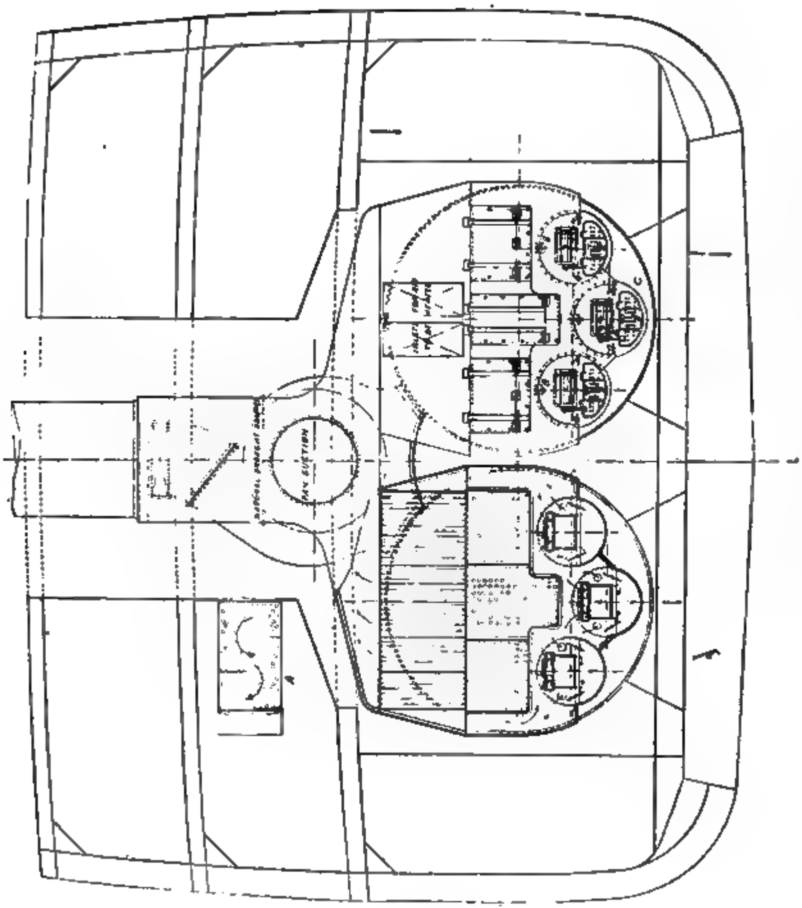


Fig. 3.—Arrangement of Induced Draught. Ellis & Eaves' System. (John Brown & Co., Ltd.)

ings in the front at the centre, and is then forced to take a circuitous course through the heater by means of vertical diaphragm plates placed at intervals, as shown in the illustration. The result is that the air is heated to over 300° Fahr. In another form of air heater used in the earlier installations horizontal tubes were used, through which the air was drawn, the hot gases circulating round the tubes.

The air passes from the heating boxes down passages on both sides of the smoke boxes, and enters the furnaces through regulating valves on the furnace fronts. One upper valve communicates with the furnaces above the bars, through baffle plates, and two lower ones with the ash-pit. The upper valve is regulated so as to prevent smoke when burning bituminous coal rich in hydrocarbons, for the combustion of which an excess of hot air is necessary.

The ash-pit is closed by a door, perforated with a number of $1\frac{1}{4}$-inch holes for the admission of cold air below the bars, and this is always made capable of regulation by a sliding perforated plate. The advantage of using a limited volume of cold air is that it keeps the bars and bearers cool; while, having to pass through the incandescent fuel, it exercises no appreciable influence in cooling the gas in the combustion chamber.

The position of the fans varies with conditions, but they are always placed to discharge directly up the funnel, and are fitted with expanding outlets which avoids risk of back pressure, and lessens the power required to drive them. The fan engine is not situated by the fan, where the heat would be too great, but in the engine room, and the connection is made by means of shafting with flexible couplings. The fan bearings are enclosed in a shell, through which cold water circulates to keep them cool. The vacuum produced by the fan varies between 2 inches and 3 inches, according to the rate of burning.

During the operation of cleaning the fires, which involves opening the furnace doors, the inrush of cold air is prevented by dividing the smoke boxes to isolate each furnace from the others, and fitting dampers, which close the communication between any furnace and the fan suction.

The rate of combustion varies with the kind of coal used. Experience has proved that an average consumption of 30 lb. of coal per square foot of grate is as much as can be maintained with economy; a falling-off of economy is generally noted at all rates of burning above this. Messrs John Brown & Co. give the following as the results of working Ellis & Eaves' induced draught in a Lancashire boiler 9 ft. diameter × 28 ft. long. An evaporation of 12,450 lb. of water per hour was obtained with induced draught, against 9,000 lb. per hour without; or 40 per cent. increase. 10·1 lb. of steam were evaporated per lb. of coal, at and from 212° Fahr., against 8 lb. of steam per lb. of coal without, or a saving of 25 per cent. Two boilers with induced draught will give as much steam as three without, so that the extra cost of the installation would be more than covered by the reduction in number of boilers.

The fire-bars in this system are of cast iron, $\frac{5}{8}$ in. thick, with $\frac{3}{8}$ in. air spaces. The side bars are fitted with a recess for ganister along the edge. The object of this is to prevent leakage of air between the side bars and the furnace, which might cause overheating if oil were present in the boiler. It was found advantageous when burning at very high rates, such as 50 or 60 lb. per square foot of grate area, to raise fire-bars 2 in. at the back and to keep them cool, but at ordinary rates of burning the bars are level.

The Ellis & Eaves' system is fitted to Lancashire boilers, to water-tube types, and to marine Scotch boilers. The latter is illustrated, Fig. 3. Differences in arrangement are involved, but that is all. The economies in each are high. The saving in fuel in marine boilers ranges from 10 to 15 per cent. over natural draught. The evaporative capacity of a boiler is increased by from 30 to 40 per cent. It is not dependent on the height of a chimney; the boilers can be forced to suit a sudden demand such as arises in electric lighting, or at sea to meet varying conditions of draught, by simply regulating the number of revolutions of the fan. The admission of the air above and below the grate, and regulated by valves, ensures the most complete combustion. The stokehold is

always cool, there can be no rush of flame backwards on opening the furnace doors, no valves to close, and no shutting of double doors as in the closed stokehold system.

The total HP. fitted with this system of induced draught is between 500,000 and 600,000. Between fifty and sixty vessels on the great lakes of the United States were fitted with it in 1905-6.

Induction.—The influence of an electrically charged conductor, whereby currents are created in other conductors coming within the magnetic field of force created around the charged body, without any apparent connection between the two bodies. The induced current will flow in the second conductor in a direction opposing that of the inducing current.

The phenomena of electrical induction are exhibited in various electrical apparatus; as in the dynamo wherein electricity is generated by its aid, in the motor where the back E.M.F. generated gives the turning moment by reactive force produced in the armature. It is in work with alternating currents, however, that induction is most strikingly effective, this property being the foundation principle of the *Static Transformer*, the *Induction Alternating Generator* (*see* **Inductor Alternator**), the "Induction Motor," and many smaller instruments and apparatus.

Reference may be made to the separate headings wherein the practical uses of the inductive capacity of electrical currents are more fully explained.

Induction Motor.—An electro-motor specially designed for use on alternating circuits. On single-phase circuits, motors in construction similar to series-wound continuous current motors may be employed (*see* **Synchronous Motors**), but "Asynchronous" or induction motors are also used (*see* **Single-Phase Motors**). Induction motors are so called because the turning power of their moving part—the *Rotor*—is produced and maintained by the reactance between currents passing in the coils of their stationary part—the *Stator*—and currents created in the rotor by induction. Thus without any apparent connection between stator and rotor the latter is made to revolve, and give at its shaft the mechanical power required.

Some of the advantages of the induction motor are:—No commutation is required, consequently there can be no sparking of brush contacts; the currents induced in the rotor are at low potential, strong insulation is therefore not required; the motor has a large overload capacity, and even if loaded up to the point of dead stoppage, no great harm can be done to the machine. The speed characteristic is between the series and shunt motor—that is, its speed whilst not constant at all loads does not vary so much as does that of the series motor. There being no insulated moving parts in connection with the supply mains, alternating current of high potential may be applied direct to their windings.

These windings, therefore, carrying small currents at high pressures, may be of comparatively small section wires; induction motors of large power may thus be built smaller than continuous current motors of similar output. Two- or three-phase motors using current at 3,000 to 6,000 volts, and giving up to 2,000 B.H.P., are in successful operation in mining, winding, pumping, haulage, &c., and also in steel-rolling mills and other industries where single units of large power are required.

Inductor Alternator.—A type of alternator generator having no moving conductors or coils excited by continuous currents.

Both field and armature windings are fixed in the stationary case. The moving part consists of a rotating iron frame, carrying laminated poles or *Inductors*. These poles periodically arriving in a position to be influenced by the field windings, and also passing the armature coils, fill the loops of the latter with magnetic flux, producing in their coils corresponding currents which may be taken off at their terminals for use in the outside circuits. Inductor alternators may be of two, three, or more phases, and usually generate current at 3,000 volts, which is then transformed up or down by static transformers, to suit the requirements for use in local circuits, or transmission lines.

Inertia.—Is that property by virtue of which matter at rest tends to remain at rest, and if in motion to remain in motion without change of rate or direction. This law

of inertia is really Newton's First Law of Motion:—"Every body continues in a state of rest or of uniform motion in a straight line, except in so far as it is compelled to change that state by force acting upon it. Inertia is, in fact, the essential property of matter. The moment of inertia of a revolving or oscillating body is the sum of the products of the mass or weight of each particle into the square of the distance of each particle from the axis of revolution. As a formula:—$I = \Sigma d^2 w$. (The Greek letter sigma is used in mathematics to denote the algebraic sum of a series.)

Ingate.—*See* **Gates, Gating.**

Ingot, Ingoting.—An ingot is a mass of cast metal or alloy, the raw material ready for subsequent treatment. In the alloys of brass and gun-metal, &c., the metal is *Ingoted*, *i.e.*, cast into ingots, when first mixed and melted. This, with subsequent remelting for actual casting into moulds, renders the alloys more homogeneous than as though they were poured

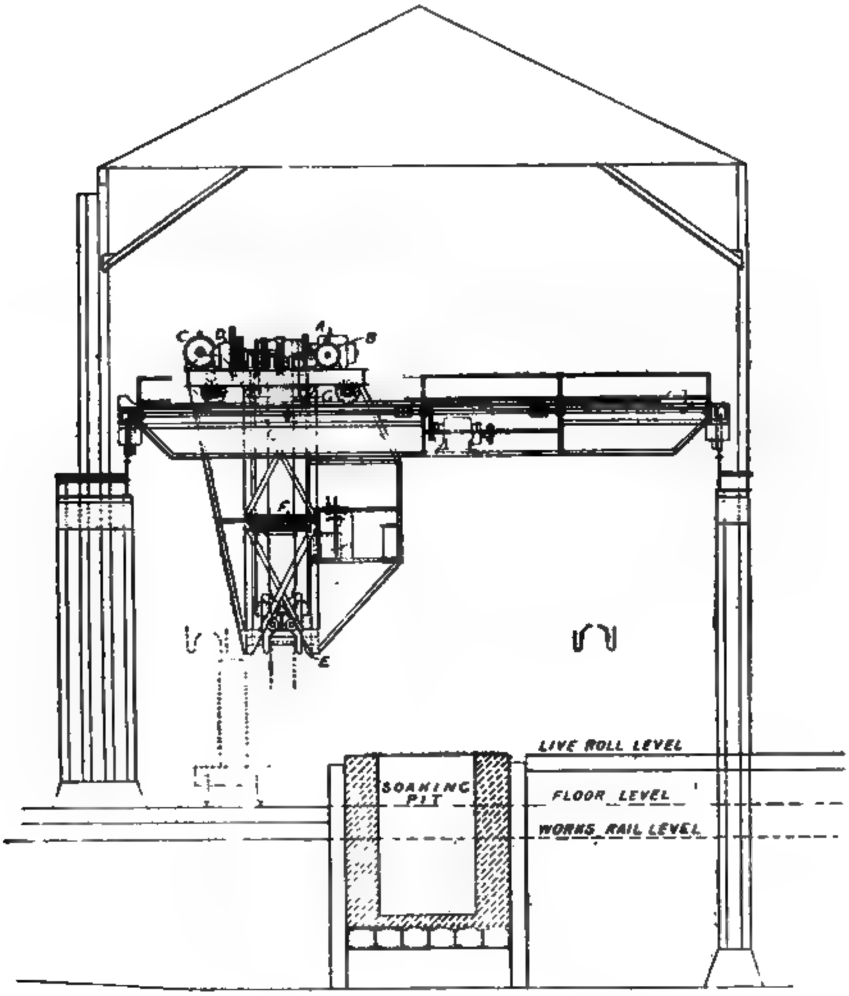


Fig. 4.—Ingot Charging Machine.

directly at the first mixing. The ingot moulds are of iron, of rectangular shape, and contain the initials of the melters.

A steel ingot is one that is poured preparatory to rolling into bars, plates, and sectional forms, and for massive forgings. As steel ingots shrink in cooling, and as this shrinkage takes place unequally, differences exist in the

degree of homogeneity of outer and inner portions, and of bottom and upper sections. Crystallisation is larger in the portions that cool last. Moreover the top of the ingot becomes drawn downwards—*piping*, and the occluded gases produce more or less of honeycombing about the upper portions. Hence two methods are in use to lessen these evils; the casting with a head, to be cut off subsequently, and the fluid compression system. Ingots are made square rather than cylindrical in section to favour the equalisation of temperature, because that form will be drawn inwards by shrinkage, and relieve the strains better than a circular form will do.

Ingot Charging Machines.—The general designs of furnace charging machines are described under **Charging Machines.** The present article relates to a type used for vertical heating furnaces or "soaking pits" which are usually situated below the level of the floor. Fig. 4 illustrates an overhead travelling crane type, electrically driven, with the following important additions to enable it to serve soaking pits. From the crab or trolley is suspended a rigid guide, within which a vertical tube carrying at its lower end a pair of tongs is free to slide up and down. These tongs are of special design, steadied by the

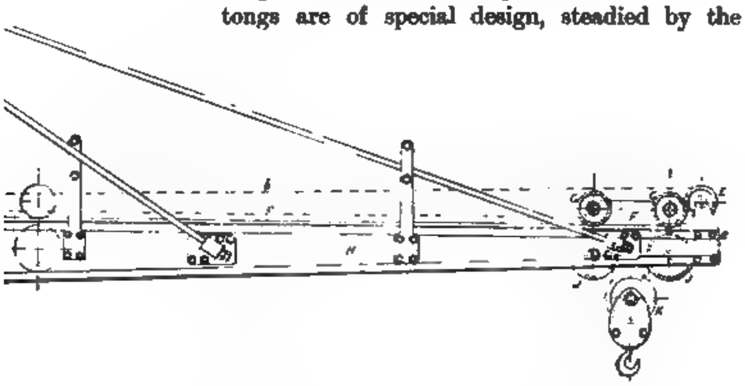
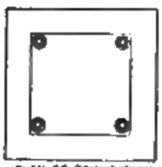


Fig. 6.—5-Ton Ingot Crane.

guides, and can be lowered by the operator into exact position for picking up an ingot in the furnace without any assistance from men on the floor level, and removing it to any required situation. The operator's cage is also generally suspended from the trolley framework, as shown, so that he may always have a good view of his work.



PLAN OF FOUNDATION

The ingots are handled in a vertical position, being lifted from cars by the gripper, and deposited vertically in the soaking pits. After withdrawal from the pits the crane deposits them on a suitable ingot tilting car for transference to the tables which deliver them to the rolling mill.

In Fig. 4, A is the hoisting motor, B the slewing ditto, C is the cross traverse motor, and D the motor for operating the tongs, E is the balance weight, F is a casting that forms the bottom guide for the charging bar, and for carrying the turning gear; G is a casting forming the top guide for the charging bar, and

PLATE I.

Fig. 5.—5-Ton Ingot Crane.
(Musgrave Bros.)

Fig. 8.—Hydraulic Ingot Stripper.
(Wellman-Seaver-Morgan Co., Ltd.)

Fig. 12.—Iron Foundry. (Niles-Bement-Pond Co.)

To face page 12.

carrying pulleys for the hoisting ropes. The span of the traveller is 35 ft., and the trolley gauge 8 ft. 4 in. It was made by the Wellman-Seaver-Morgan Co., Ltd.

Ingot Crane.—A crane designed specially for, or adapted to the work of ingot stripping. The original type is a direct-acting hydraulic jib crane, see Fig. 205, Plate XV., in Vol. V.; the height of lift being equal to the lift of the ram. These cranes are either independent on a foundation, or top-supported. Another design is that shown by Fig. 5, Plate I., a five-ton crane made by Musgrave Bros., of Leeds, for the Frodingham Iron and Steel Co., Ltd., and in elevation by Fig. 6 adjacent. It is a top-supported crane, the journal being seen at the top of the mast. The jib is a rigid one, sustained by two sets of tie rods. Five hydraulic cylinders are required for its operation; two, A for turning or slewing; one, B for racking outwards; one, C ditto inwards; one, for lifting, placed between the two channel sections of which the mast is built. Taking these in order:—The ram of A in moving downwards extends the chain anchored at *a*, and turns the chain wheel D at the foot of the mast in one direction; and a duplicate cylinder in line with it is for turning in the opposite direction. The cage for operating the levers for these, as well as the other cylinders, is seen at F; the levers themselves may be observed in the photo, Fig. 5, Plate I. The racking cylinder B, the reference letter being placed on its top pulley, moves the rope *b* passing round the guide pulley E at the end of the jib, and anchored to the outer end of the jenny or racking carriage F, for drawing the carriage away from the post. The rope *c* from the cylinder C is attached to the inner end of the carriage for drawing it towards the post. The extreme direction of the jenny in this direction is indicated at L. The lifting cylinder D has its rope anchored at *d* at one end, and at *e* at the other. The rope *f* passes round a guide pulley at *g* over one of the guide pulleys J in the carriage, down over the snatch block pulley K, up over the second pulley J to its anchorage at *e*. The effect of thrusting the ram of D outwards is to raise the load. To lower, the pressure water is shut off, the escape valve opened, and the load then descending by gravity pushes the ram back into its cylinder. The whole weight of the crane is taken on ball bearings, and the hook is also fitted with a ball race.

Ingot Iron.—A term once used more than at present, to denote the milder qualities of open-hearth steel, or those very low in carbon.

Ingot Mould.—A mould of cast iron for pouring steel into. It is of grey hæmatite pig, of various sectional shapes, but mostly square or rectangular, with enough taper lengthwise to permit of *stripping*, or lifting it off the ingot, for which eyes are provided. Ingot moulds are generally poured or *teemed* from the top, resting on thick cast-iron bottom plates. They endure from 50 to 100 castings. Fig. 7 shows a mould by the North-Eastern Steel Co., Ltd.

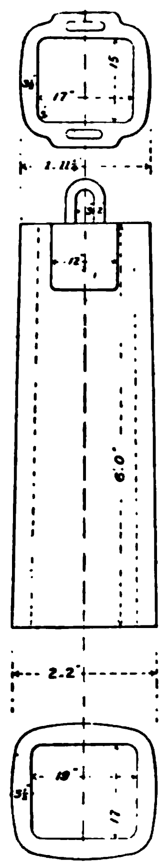


Fig. 7.—Ingot Mould.

Ingot Saw.—*See* **Hot Iron Saw.**

Ingot Stripping.—Drawing ingot moulds from steel ingots. The soaking pits are usually below the floor level, and served by specially designed cranes or charging machines. The ingot strippers are constructed on the general lines of an overhead electric travelling crane, like that in Fig. 4, page 11, or as a Goliath framing. See Fig. 8, Plate I., which shows a hydraulic type made for the Tennessee Coal, Iron, and Railroad Co., Ensley, Ala. A telescopic device strips the mould from the ingot, by lifting the mould, while at the same time it prevents the ingot itself from being lifted with the mould from the car. When the strippers are of the travelling type, the moulds can be lifted from the ingots at any place along the runway beneath the bridge of the crane, and deposited in any convenient position.

Ingot Tilter.—A machine for turning over an ingot through an angle of 90° between successive passes of the rolls. The tilting is effected by tappets on a trolley. Details vary, according to whether the mills are of reversing, or of non-reversing type.

Injection.—Relates to the water required

DELIVERY

Fig. 9.—Injector. (Holden & Brooke, Ltd.)

for the condensation of steam in a jet condenser. *See* **Condenser.**

Injector.—The injector is an instrument employed for feeding boilers with water; and works by the direct action of steam upon the water to be forced into the boiler. It is therefore essential that the water shall be able more or less completely to condense the steam. This does not necessarily mean that the mixed steam shall have a temperature less than 212° Fahr., but it is essential that the temperature shall be lower than that of the boiler into which the steam flows. It can be shown by simple elementary arithmetic that the action of the injector is perfectly simple, though it is often referred to as mysterious, especially as regards the exhaust steam injector, which, working with steam at atmospheric pressure, will force water into a boiler at 70 or 80 lb. gauge pressure. A simple calculation will show how this is possible. Let exhaust steam, 1 lb., be
ıt 212° Fahr., and say 7·6 lb. of water at
he combined stream has a temperature of
ıe water being heated 130° Fahr., and the
ıaving lost 966 + (212 − 190) = 988 thermal
Then 988 ÷ 130 = 7·6 lb. of water. The
tream weighs 8·6 lb. per lb. of steam
The velocity of flow of steam into a
ı is, say, 1,800 feet per second. All
ocity is in the steam, the water merely
lowly to the injector. Then the com-
/elocity of flow of water and the steam
lenses will be 1,800 ÷ 8·6 = 210 feet per

known that the velocity of flow of water
ı $\sqrt{h}$, when h = head in feet, whence we
$\sqrt{h}$ = 210 ft. per second, and $\sqrt{h}$ = 210
6, and $h = 26^2 = 676$ ft. This head of
corresponds with a pressure of 291 lb.,
it is easy to understand how the injector
d into a boiler at 80 lb. With higher
e steam, higher pressures can be fed
. Speaking generally, of course, the
the water and the higher the steam pres-
ıe smaller may be the jet, and the greater
e its velocity and penetrative power.
The injector is merely a heat engine, and as such, is dependent upon the thermo-dynamic law, which says that the efficiency cannot exceed $\frac{T_1 - T_2}{T_1}$, where T_1 and T_2 are the absolute temperatures of the steam, and of the combined jet.

An injector consists of a series of carefully formed cones. Steam enters by a narrow conical passage A, Fig. 9, contained inside a wider water cone, the two cones converging at the so-called combining point B, where the energy of move-

ment of the steam is conveyed to the water in which the steam condenses. The jet is now forming, and is under no pressure, all its energy being now kinetic, or velocity energy. Along the combining cone there are lateral escape holes through which the water can flow to waste E, pending the complete establishment of the solid jet. As soon as this is effected the jet can pass through the throat above D. This is the entrance to the coned passage which leads the formed jet to the boiler into which the jet penetrates, its energy of movement being reconverted into pressure in the flared-out cone beyond the narrow throat. The diameter of this throat is always stated in millimetres, and this is the size of the injector. Thus a No. 2 size has a throat of 2 mm. diameter. The capacity of injectors varies, other things being equal, with the square of the diameter of the throat.

In the case of exhaust steam injectors, the overflow apertures are replaced by more capacious means of escape. In one form the combining cone is split longitudinally and hinged at one end so that it falls open automatically, and only closes to form a solid cone when the jet is established, and vacuum produced in the combining space. A formula for the velocity of flow of steam per second is $V = 8\sqrt{\frac{nP}{n+R}}$ when n is a coefficient varying from 1 to 1·4, P = pressure in pounds per square foot, and R = weight of a cubic foot of steam at pressure P; or $V = 8\sqrt{\frac{n}{n+1}}$ PW when W = volume in cubic feet of 1 lb. of steam, and n is the exponent in the term PV^n = constant.

Approximately $V = 6\sqrt{\frac{P}{R}}$, the true figure, being 5 per cent. less for wet and 2 per cent. greater for dry steam. The output of an injector for any pressure is $G = D^2(P + 85)$ where G = pounds per hour, and P = absolute pressure per square inch, D being the throat diameter in millimetres.

The discharge of exhaust steam injectors appears to be $G = 170\ D^2$. For steam of 60 lb. a No. 2 injector will ordinarily deliver 1 gallon a minute, a No. 12 delivering 36 gallons. At 200 lb. these figures may be doubled. Few injectors will lift more than 18 feet, and the water must not exceed 75° Fahr. for maximum output.

The Ejector.—This is simply a form of injector which is used to move liquid or gas often in considerable quantity, but against small pressure.

Thus an ejector may be employed to empty a vat, or to raise a liquid from one floor to another. In the ejector condenser the action is exactly that of the exhaust injector, the water flowing to the ejector at as high a velocity as can conveniently be given to it, and steam combining and condensing in the stream which is urged forward by the momentum of the condensed steam at a velocity commensurate with the vacuum that is attained by the instrument. Under ordinary conditions this will not be less than 24 inches of mercury column. Generally the cones of an ejector are capacious, so that the instrument will deal with large volumes of water at low pressures rather than with small volumes at high pressures.

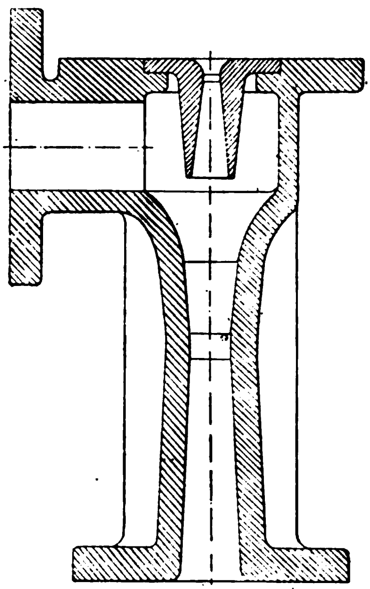


Fig. 10.—Ejector. (Holden & Brooke, Ltd.)

In the vacuum brake, the "vacuum" is produced by the eductive action of a form of steam ejector which draws out the air from the train pipe. Steam jets as applied to the urging of fires also come under the classification of ejectors rather than of injectors.

In all cases the theoretical momentum of the

combined jet is the mean of the momenta of the working jet, and of the liquid it forces along with itself, and for low-pressure work it is not necessary for the working fluid to be condensed. The necessity of condensation arises where the energy of the jet is insufficient in comparison with its bulk to do the work necessary to force such bulk against a given resistance. Thus, in forcing a cubic foot of material into the atmosphere from a vacuous space, the work done is equal to 144 by 14·7, or 2,117 lb. moved one foot, that is to say, to the product of the area in square inches by the pressure per square inch and the distance of movement, the result being in foot pounds. Dividing this by 772 gives the energy in heat units as barely 3 B.Th.U. For steam containing about 100 B.Th.U. per pound, the weight required will be obviously $\frac{3}{1000} \div$ efficiency. Now the efficiency of a heat fluid being $\frac{T_1 - T_2}{T_1}$ and an injector working between the temperatures of let us say 220° and 120°, the efficiency will be for such a case $\frac{680 - 580}{680}$, or about 15 per cent.; so that at least $\frac{1}{5}$th of a lb. of steam would be required theoretically to force a cubic foot of water against a pressure of one atmosphere if the water were at such temperature that the combined mass had a final temperature of 120° Fahr., or say 580° absolute. Still more would be required by reason of the losses due to mechanical inefficiency, such as the formation of eddies, &c.

Though exhaust steam injectors will only force water against a certain limited pressure, they may be supplemented by a jet of higher pressure steam, when a greater pressure may be fed against, and the economy due to the use of the exhaust steam will still be secured.

Certain fire hydrants are worked by high pressure water jets and ejectors, the action of a very high-pressure jet of water carrying forward a large jet of ordinary town's water for producing a jet of large volume for fire extinguishing purposes.

Insertion.—Relates to the joints of the flanges of steam pipes, which are made by inserting a sheet of indiarubber between the faces of the flanges. *Insertion sheet* contains a layer of woven brass wire in the middle of the indiarubber.

Inside Calipers.—*See* **Caliper.**

Inside Cylinders.—Relates to the position of the cylinders in locomotive engines, whether inside the framings, or outside. *See* **Locomotive Engine.**

Inspection.—The work of examination of manufactured articles, done both during the process of manufacture, and on completion. It includes ocular examination and mechanical testing of castings, forgings, plated work, boiler work, machining, fitting, erecting, and finishing. It is usually defined by the terms of specifications, but beyond that an inspector has generally unlimited powers, since a clause—"to the satisfaction of the inspector," is usually included. The duties are heavy, and should include extensive knowledge of practice, though this is often deficient. But when inspectors have been trained in one particular set of duties, as testing of materials, steam boilers, and engines, &c., they become highly efficient.

Instantaneous Centre.—A centre the position of which constantly changes in space, and therefore the opposite of a fixed centre. *See* **Closed Chains.**

Instantaneous Grip Vice.—*See* **Bench Vice.**

Insulation—Insulators.—The isolation of charged conductors by a dielectric interposed between the + of the source of charge and the earth; or the covering of conductors with materials of such comparatively high resistance as renders them practically non-conductive of electricity.

The term *Insulator* is only a relative one, or a measure of resistance, there being no form of matter which is an absolute non-conductor. The value of a material as an insulator depends therefore upon its resistance, and also upon its non-hygroscopic qualities.

Thus, whilst wood, silk, cotton, asbestos, &c., in a *dry* state are good insulators, such materials cannot be used in exposed or damp situations where they would absorb moisture and become more conductive, or where atmospheric changes would result in moisture forming by condensation upon their surface. For these reasons the best insulators are of materials

which are not only non-absorbent, but are also capable of receiving a highly glazed surface. Porcelain, glass, ebonite, mica, &c., having these properties, form the best insulators for separating conductors in exposed positions. The metallic conducting parts of switchboards, &c., are usually insulated from each other by being mounted on slate or marble slabs, the latter being the better material. But whilst the slate or marble can receive a highly polished surface, and so prevent "surface-leakage," they often contain particles or veins of iron or other metals; it is therefore usual to employ insulating bushes of porcelain or ebonite in the mounting of the various parts, and to insulate the board as a whole from earth.

When wood blocks, bushes, &c., are used for insulators, they should be waterproofed by dipping in melted paraffin wax, or by several coats of shellac varnish. Teak is found to be the most suitable wood for electrical purposes, containing a natural oil of high insulating value; and not being liable to split or warp it is also less subject, in tropical climates, to the attacks of insects. There are now many kinds of insulating compositions — ebonite, micanite, roburine, ambroin, &c., which are exceedingly useful to the electrician, as they can be moulded into suitable shapes for the various requirements of his work, and are, when made in quantities in this manner, comparatively inexpensive.

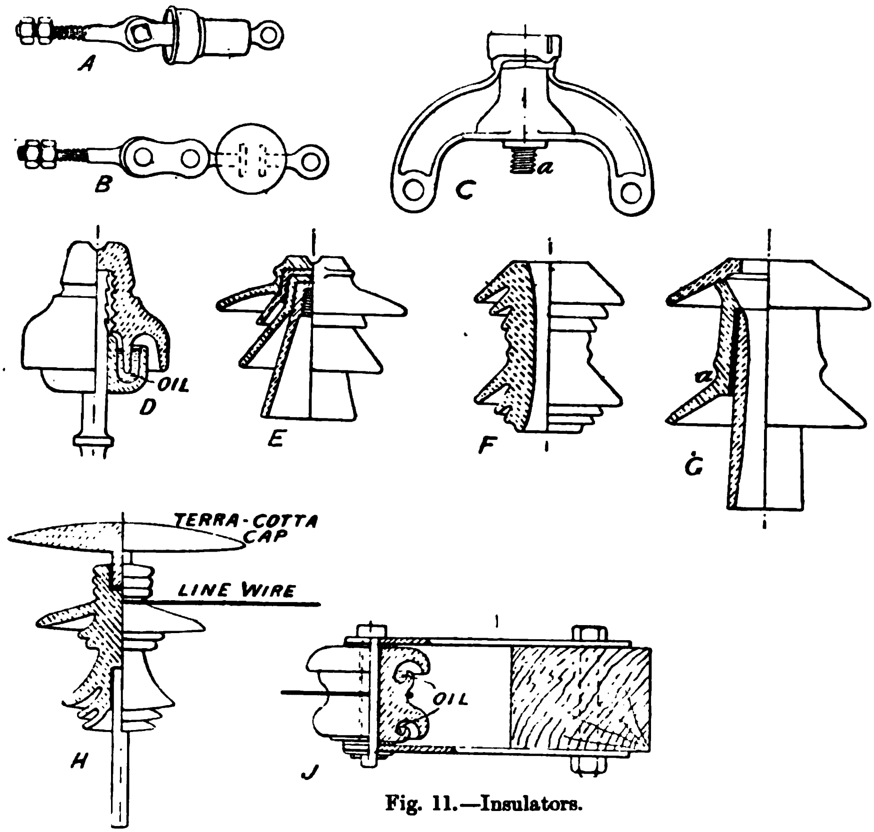


Fig. 11.—Insulators.

The value of a glazed surface can be seen by dipping bodily into, or spraying water upon the surface of a porcelain or micanite insulator. It will then be seen that not only does the water not penetrate the glaze, but that instead of forming a film, it immediately collects into small globules which quickly fall off, or, if current be passing in the conductor carried by the insulator, are at once evaporated by any leakage of current taking place, leaving the

surface dry and polished as before. All the various forms of insulators used in overhead construction work for electric tramways are moulded from compositions consisting of fossil-resins and silicates, mica, &c. Some types of these are shown in Fig. 11, A, B, and C. For telegraph, telephone, and low-tension transmission lines, porcelain or brownware insulators, cemented on to upright bolts, are used. For higher pressures a form shown in D, Fig. 11, was for a time adopted, wherein a small oil reservoir containing creosote or resin oil gave additional security from surface leakage. These are effective, but require careful erection to see that no oil is left upon the edges of the reservoir or surface of the insulator, otherwise a caking of dust soon forms which may be the cause of failure of insulation, and will not wash off by rain. For the extra high pressures now used in power transmission lines, a pattern of vitrified, highly glazed porcelain insulators, shown in Fig. 11, E, F, G, has been adopted, reliance being placed upon the interposition of a number of steps or "petticoats" to throw off rain or prevent the formation of moisture films by condensation. These types of insulators are successfully used on line constructions carrying pressures up to 60,000 volts. For the termination of high-pressure lines, such an insulator as E, Fig. 11, or an arrangement as in J is used, a special sealing insulator being provided to protect the end of the insulated cables entering the building, as shown in G. The latest pattern of line insulator for extra high-pressure lines is shown in H, Fig. 11.

Electric cables, wires, &c., are insulated by a continuous envelope of flexible insulation formed of braidings of cotton, silk, jute, hemp, &c., or a covering of gutta-percha, indiarubber, vulcanised bitumen composition, spirally wound strips of paper impregnated with special insulating oils, or by some combination of these or similar non-conducting materials. The best insulating medium is air (*see* **Dielectric**), so that conductors, if in situations where they are not liable to mechanical damage, or where they cannot come into connection with earth, are often erected without an insulating covering, being supported on suitable porcelain or other insulators.

Insulation Resistance.—Insulation being a measure of resistance; its value is measured in ohms or megohms as Insulation Resistance.

The insulation of a conductor varies with the stresses to which the insulator is subjected. Ohm's Law, $R = \frac{E}{C}$, applies to insulation resistance, but as R for an insulating material must be very high, it is usually measured in millions of ohms or megohms (Ω). Thus, suppose a current of 100 amps. at 500 volts to be carried by a conductor, if the insulation were only equal to 10 ohms, then $\frac{500 \text{ volts}}{10 \text{ ohms}} = 50$ amps. would be wasted in leakage to earth. For such a case R should equal 5 Ω, giving a leakage of current of ·0001 amp. before it could be said to be insulated sufficiently for safe working. To the engineer working with electrical plants the insulation resistance between the + and − parts of the machinery and circuits is a most important matter, to be thoroughly secured in the first place, and carefully tested from time to time so that faults may be detected and repaired.

It is commonly understood that a leakage of electricity is to be provided against as much as a leakage of gas or water. This is so, but not quite for the same reasons. That is to say, the expense of wasting the current is not a chief consideration. A fault in the insulation of an electric circuit may be so small a matter that it would be of no consequence considered as a leakage, but it will develop, and at some time will cause a complete breakdown, with possibly serious results. Suppose we have a motor connected by switchgear and cables to the supply mains. The current flows along the + conductor to the motor + brush, then from the − brush returns to the dynamo.

We may connect the − to earth, and no harm would be done, *so long as we keep the + side insulated* from the − side and earth. But if + and − come together, or both become earthed at any point with good contact, heavy currents will flow through the low resistance of the fault. The fuses will blow, and the motor cannot be run again until the faulty place is discovered and repaired.

If the fault be only a partial contact the current will have some resistance, but having

once made contact an arc will be formed, the covering of the cables may be ignited, and a fire result. Great care should therefore be used in erecting or laying cables that their covering be not damaged, and that no metal parts of the switchgear of opposite potential can become connected with each other or in contact with earth. When the motor, switchgear, &c., are connected, and before current from the mains is applied, the insulation of the whole circuit should be tested by proper instruments (*see* **Ohmmeter**), the result, if satisfactory, should be recorded, and the tests repeated from to time. Any deterioration of the insulation can thus be observed and repaired before complete breakdown occurs.

If no special instruments are available, a rough test may be taken with a portable voltmeter. Connect one terminal of the instrument to the + brush of the motor, and the other terminal to earth. There should then, if the insulation is good, be no reading on the voltmeter. If, however, a reading equal to more than 3 per cent. of the full circuit voltage is shown, the insulation to earth is not good enough for safe working. Each part of the circuit should be successively disconnected (motor, switch, cables, &c.), until the reading disappears, whereupon the section last cut out will be the faulty one, and thus located, the necessary repairs should be at once carried out. This method has the advantage that the full working pressure is used for testing, and the fault is more likely to be discovered thus than by using a battery and galvanometer, or electric bell. *See also* **Earth, Dead Earth,** &c.

The parts of the motor requiring special attention in regard to insulation are the insulating bushes, or plates of the brushgear. These parts must be kept quite clean, and copper, or carbon-dust, or oil must be prevented from collecting on their surfaces. The ends and insulating rings at the ends of the commutator bars must be kept clean, as oil is sometimes thrown up on them, especially if too much oil is supplied to the bearings, although means to prevent this are usually provided. But if the motor is not carefully lined up to the shaft it drives, or a crooked belt is fitted, the end-play which then occurs will result in oil being thrown up from the most carefully designed bearing, and if not attended to, this will work its way into the mica insulation of the commutator bars, and the commutator, and possibly the armature coils, will be burnt out.

Careful work in installation is most necessary for all electrical apparatus. It is then less likely to give trouble than any other kind of machinery, but faulty or careless work will inevitably cause trouble sooner or later. *See also* **Testing, Electric.**

Intensifier.—*See* **Accumulator, Hydraulic.**

Intercepting Valve.—A valve fitted to some compound locomotives, as the Worsdell, and Von Borries, and in some Schenectady engines, the function of which is to admit steam from the boiler directly to the low-pressure cylinder at the starting of the engines, or in case the low-pressure crank is on dead centres. It comprises a piston valve on the low-pressure cylinder which receives boiler steam from a reducing valve, in which the pressure is reduced to that at which the low-pressure cylinder receives its steam in the ordinary way. The arrangements of valves and passages are such that while there is full boiler pressure in the high-pressure cylinder, and reduced pressure in the low-pressure cylinder, there are no counteracting back pressures. In other words, while there is low-pressure steam introduced on one side of the piston, the high-pressure steam cannot come on the side opposite. The action also is automatic. After the engine has started, the intercepting valve is rendered inoperative, and the engine works compound.

Interceptor.—A vessel which contains a diaphragm plate to prevent water being carried with steam into the cylinders of marine engines. The water is thrown down by the diaphragm, and run off by a drain cock.

Interchangeable System.—The method of manufacture in which all individual elements in a given mechanism will fit equally well in any other mechanism of the same kind, without hand fitting, or hand adjustments of individual pieces. To ensure this, all pieces are machined to gauges, having minute limits of tolerance on each side of exact dimensions.

Intercooler.—*See* **Air Compressor.**

Intermittent Gears, or **Mutilated Gears.** —Segments of toothed wheels having portions cut away in order to substitute intermittent for continuous action. A large number of these are possible. The tooth shapes are the same as those which are employed in the corresponding types of full gears.

Internal Corrosion.—*See* **Boiler Explosions.**

Internal Flues.—*See* **Furnace Flues.**

Internal Gears.—Practically restricted to spur gears, though internal bevels, and spirals can be constructed. Internal spurs are commonly used for convenience of arrangement when arms cannot be inserted, the space being otherwise occupied. The shapes of the teeth are identical with those employed on spur gears, only reversed. In cycloidal teeth, the curves of the internal teeth have their faces corresponding with the flank curves of external teeth, and their flanks corresponding with the face curves of external teeth. In the involute the teeth have the same curves as an external wheel of the same size, but the tooth flanks are concave instead of convex.

Internally-Fired Boilers. — Boilers in which the furnace is enclosed by the shell. All boilers now made are of this type. The Cornish was the first in which the practice was introduced, followed by the Lancashire and others.

Inverted Bridge.—*See* **Hanging Bridge.**

Involute Teeth.—*See* **Gears.**

Inward Flow.—Relates to the method of bringing water into turbine buckets. It means that the guide wheel through which the water enters and drives the buckets, encircles the latter. The method is adopted in both reaction and impulse types. *See* **Turbines.**

Iron.—Commercial iron owes its exceedingly valuable properties not to its purity, but to its capacity for combining with a number of other elements in very various proportions. Hence the production of iron and steel is based upon chemical affinities, the reasons of which, unknown in the incipient history of iron manufacture, are now intelligently understood, and regulated by those who have the management of iron works. The principal foreign elements which vitally affect the properties of commercial iron are carbon, silicon, manganese, oxygen, phosphorus, and sulphur. Titanium, arsenic, and tungsten may be present in small amounts. With the exception of potassium, sodium, and the small group of metals of that class, there is none which is so greedy of oxygen at ordinary temperatures as iron. Hence scarcely any trace of pure iron exists in Nature. Almost all ores of iron, all the important commercial ores, in fact, are so intimately combined with oxygen that their metallic character is disguised by the earthy matters—oxides, or carbonates with which they are combined. The one notable exception is meteoric iron, which has been found upon various parts of the surface of the earth. But this is of extra-terrestrial origin, and from wheresoever derived is of no account from the manufacturers' point of view, being rather a curiosity as a visitor from other worlds.

Next comes the comparatively pure magnetite, or magnetic iron ore. To this class the loadstone belongs. These ores are widely diffused and are very valuable, that quarried from the celebrated Dannemora mine in Sweden having long enjoyed a pre-eminent reputation. There are nevertheless some impurities, such as phosphorus and sulphur, and apatite sometimes found in association with the ore. Its chemical formula is $Fe_2O_3 + FeO$. It is therefore a compound of ferric and ferrous oxides. Fifty to sixty per cent. of pure iron is a good yield from these ores.

The red and the brown hæmatites are oxides of iron, being the ferric, or peroxides. But they differ in the fact that the red hæmatites are anhydrous, while the brown are hydrated, the amount of water being variable in different specimens. The red is represented by Fe_2O_3; the brown by $2Fe_2O_3 + 3H_2O$. Both are rich ores, though of less commercial value than some of the more impure ores. The red hæmatites are mined in Cumberland, Lancashire, and Glamorganshire; while the brown are of less value in England as a source of iron than they are in France. The red hæmatites contain from 60 to 65 per cent. of iron, and the brown from 40 to 60 per cent. In some of the brown ores silica is present to the extent of 34 per cent.

The most important ores of iron from the

industrial point of view are those of the Carboniferous period, and known by different names according to their appearance, character, and surroundings. The most important English source of iron is variously termed Spathic, Clay band, Clay iron-stone, and Argillaceous ores. The composition of these is variable, but they are essentially hydrated oxides and carbonates of iron, with a large admixture of clay, hence the names Clay band, and Argillaceous. Nearly two-thirds of the total weight of pig iron extracted in Great Britain is derived from these ores. In the Black Country, Derbyshire, Yorkshire, and in South Wales, they occur in abundance, and notwithstanding that the percentage of iron is small, averaging perhaps 25 to 35 per cent., they are smelted economically, because the coal measures in which they occur supply the fuel for their reduction without the cost of transit. In Scotland there is a clay iron-stone, the Black-band, the bituminous matter in which imparts a dark appearance to the ore. Deposits of this are found in Lanarkshire and Ayrshire, and the presence therein of coaly matter is a source of economical working, because the calcination is effected without the use of additional fuel.

The compound of iron with sulphur, known as iron pyrites, is of no value to the smelter, being employed for the production of sulphuric acid.

Few ores of iron give any indication to the casual observer of their metallic basis, or of their immense value. The spathic and magnetic ores have a lustrous appearance, which betrays their metallic property, but the ironstones have a dull appearance, and the hæmatites are found either in globules or in a state of powder. In all of them the iron is either in a condition of chemical combination, or of mechanical admixture, or of both, with foreign substances, and the iron smelter has to effect the removal of these deleterious admixtures from the metal.

It will assist us if we take a fair typical sample of a Cleveland iron-stone, and note its constituents :—

Ferrous oxide (FeO)	39·92
Ferric oxide (Fe_2O_3)	3·60
Carbonic anhydride (CO_2)	22·85
Manganous oxide (MnO)	0·95
Alumina (Al_2O_3)	7·86
Lime (CaO)	7·44
Magnesia (MgO)	3·82
Potash (K_2O)	0·27
Silica, and insoluble residue	8·76
Phosphoric anhydride (P_2O_5)	1·86
Pyrites (FeS_2)	0·11
Water (H_2O)	2·97
	100·41

Metallic iron present - 33·62 per cent.

Omitting the minor constituents for the present, the principal compounds present in the ore are the oxides, and carbonate of iron; or the ferrous carbonate produced by the union of ferrous oxide with carbonic acid, thus: $FeO + CO_2 = Fe + CO_3$. All the iron is disguised by having entered into combination with oxygen. To separate these therefore is the principal object, and in order to effect that, something must be introduced into the furnace which will have so great an affinity for the oxygen as to cause it to quit the iron and combine with the substance introduced. Oxygen has a greater affinity for carbonic oxide, CO, at a red heat than it has for iron, converting it into the higher oxide, CO_2. Hence by introducing and heating to redness in the presence of air a substance rich in carbon, CO will thereby be produced, and will attract the oxygen from the iron, leaving the latter in the metallic or *reduced* condition. Carbon, or more strictly its oxide, CO, is the *reducing agent*, and this carbon (coke or charcoal) when heated to a white heat, will also perform the additional task of rendering fluid the reduced iron.

But there remain the silica, alumina, magnesia, and other matters which go to make up the infusible matrix or *gangue*. Their presence would effectually forbid the carrying on of smelting operations to perfection, because they would mix with the metal, rendering it spongy, and prevent homogeneity of its particles. Obviously a substance must be sought for which will render these refractory materials so fluid that they shall separate from the reduced metal by the difference in specific gravities. Limestone is the agent which, better than any other, combines with the

silica and alumina to form a light slag, through which, when fluid, the heavier iron sinks to the bottom of the furnace; hence limestone is added to the charge or *burden* of the blast furnace in order to *flux* off the silica and alumina.

As the clay band ore is essentially or chiefly a ferrous carbonate, that is, it contains iron and oxygen combined in equal parts (protoxide), and also carbon and oxygen in the proportions necessary to form carbonic acid, its formula is $FeO + CO_2$, or $FeCO_3$. But the iron really enters into the blast furnace in the ferric condition (peroxide), that is, there are two parts of iron to three of oxygen, its formula being Fe_2O_3. For the carbonate is got rid of in the preliminary process of roasting or calcination; a process formerly carried on in open heaps, but now effected in properly constructed kilns contiguous to the blast furnace, so that the roasted ore, while still hot, is run from the kilns to the blast furnace direct. Hence the actual reduction which goes on in the latter is that of ferric oxide simply.

The charge for a blast furnace therefore consists of three ingredients only, the ore, the fuel, and the flux, and the proportions of each of these will vary in different localities with the nature of their respective compositions. Thus, too, either charcoal, or coal will be used as fuel, or the flux will be of an argillaceous character when the ore is highly calcareous. But speaking in a general way, in reference to clay band ores, the fuel consists of coke, and the flux of limestone. The coke is hard, or furnace coke. The flux is the ordinary limestone usually found associated with the ore, broken up into lumps of convenient size. Before charging the furnace with a new variety of ore, it is necessary to ascertain quantitatively its composition. For this purpose chemists are kept at all iron works, whose task is to ascertain by analysis the compositions of ores, fuels, and also of slags. The percentages of these being determined, the proportions of the burden are adjusted accordingly.

The charge or burden is thrown in at the top of the furnace. The first change which the ore in the state of impure ferric oxide, plus the gangue or earthy matter, undergoes as it sinks downwards, is its conversion into a porous mass of partially reduced iron by the agency of carbonic oxide derived from the fuel and from the blast. The two oxides of carbon play the most important part in the reduction of iron, CO being the principal or actual agent; and a constant interchange is going on in the ascending zones, of the stratified contents of the furnace, between the molecules of oxygen and carbon, which in turn react upon the iron. In the lower part of the furnace the oxygen is in excess, being derived from the blast, and there carbonic acid, CO_2, is immediately formed. As the gas ascends it comes in contact with a stratum of heated fuel, the carbon of which abstracts a molecule of the oxygen, leaving carbonic oxide only, CO, thus $CO_2 + C = 2CO$. The carbonic oxide again passing upwards, and meeting with a mass of ore, reduces it by combining with its oxygen, being itself changed into carbonic acid again, according to the equation $Fe_2O_3 + 3CO = 3CO_2 + 2Fe$. The CO_2 again meeting with more fuel becomes reduced to CO; and so this process of interchange of molecules goes on until the upper and cooler portions of the furnace are reached. Moreover, as the metal sinks down into the hotter zones of the furnace, and the clayey matters are rendered more fusible by the limestone flux, some portion of the carbon in the fuel combines with the iron, and probably some portions of the oxides of carbon undergo dissociation, leaving pure carbon, with which also the iron enters into combination, and being thereby rendered fluid, sinks down into the crucible or hearth. The reactions which take place between the ore, the fuel, and the gases must be repeated many times during the progress of the ore from the upper and comparatively cool zones down to the vicinity of the tuyeres. It will be also evident that the temperature of the various zones is a matter of much importance, since, if low, the reactions will not take place so completely as though it were maintained at a higher point. Hence, other conditions being the same, the make and the quality of the iron depends upon the temperature, a high degree being conducive to the production of a fluid iron rich in carbon.

The white variety of cast iron, in which the carbon is present in the combined condition, is

the material from which wrought or malleable iron is subsequently produced, by a process which is mainly one of decarbonisation. The differences in quality, ranging from the Staffordshire products to those of the Farnley and other Yorkshire houses, are due largely to differences in the methods of refinement adopted. *See* **Wrought Iron**.

Iron is so greedy for oxygen in the presence of moist air that it becomes corroded, or converted into oxide, unless measures are taken to prevent contact of it with the air by paint and other protective coatings.

The *slags* from the blast furnace vary in colour and composition according to the nature of the ore and fuel and the conditions of working, but essentially they are all double silicates of lime and alumina, according to one or other of the formulæ—$3(CaO, SiO_2) + Al_2O_3, 3SiO_2$; or $3(2CaO, SiO_2) + 2Al_2O_3, 3SiO_2$.

Iron Bark (*Eucalyptus siderophloia*).—There are several trees that bear this name, but the species given above is the one best known, and most commonly used. It is plentiful in New South Wales and Queensland. It reaches a height of 150 ft., with a diameter of 4 ft. The wood is of a dark red colour. It is one of the hardest and strongest kinds, its transverse strength being about half that of wrought iron. It is readily attacked by the *Teredo navalis*, and develops star shakes. The average weight of a cubic foot is 72 lb., its transverse strength ranges from 950 lb. to 1,050 lb. per square inch, and its crushing strength is about 5 tons per square inch.

Iron Cement.—Iron borings and turnings mixed with sal-ammoniac, and used for caulking joints in tank plates, in socketed pipes, and in many similar articles. The borings are passed through a sieve with a mesh of from $\frac{1}{8}$ in. to $\frac{1}{4}$ in., according to the thickness of the joint, mixed with sal-ammoniac, about 1 oz. to the cwt., and moistened with water. Sulphur may be added. The cement in the form of a loose paste is *stemmed*, or caulked into the joint with hammer blows dealt on a caulking iron.

Iron Founding.—This embraces numerous sections, and has become greatly differentiated in the larger shops of late years. A few years since it was not very uncommon to meet with men who had gathered experience in nearly every department of the iron founder's work; in green, and dry sands, in loam, and core making, in light work and heavy, and in some cases, in machine moulding of toothed wheels. Such men grow scarce, because there is now no place for them except in the smaller shops. As the principal sections of iron founders' work are described under specific heads, the following observations relate to the work of the foundry as a whole.

Small Foundries doing Jobbing Work.—This means that a foundry takes any class of work that comes along, as far as its capacity and tackle will permit of. Such foundries are indispensable in the smaller towns, and in country towns, surrounded by extensive rural districts. They must be ready to work in loam and dried sand, much of which is of a makeshift character, as moulding from broken castings, or from patterns made by carpenters and amateurs. There is often much makeshift with tackle, and boxes, because single jobs will not pay for special boxes. A good deal of bedding-in is done that would be better turned-over if boxes were available. There is much sweep work to save the cost of patterns; many skeleton patterns are used; loam patterns and loam moulds are used for the same reason. Several different grades of iron are often required during a day's blow, and quantities of scrap are utilised, being bought for a trifle. The leading men are handy, prompt to scheme, and ready to do any class of work, whether rough and cheap, or involved and costly, to suit a varied class of customers.

Large Foundries doing General Work.—These include foundries unconnected with an engineer's works, though the larger number are a department of an engineer's factory, but with facilities for taking outside orders. The advantage is that a large source of profit is tapped, and any slack periods in the firm's own work are tided over without discharging valuable hands. In such foundries there is much specialisation. The light and heavy sections of each group are kept distinct, in green sand, loam, and cores, and generally there is a machine department for repetitive work. Many engineers' shops prefer to put out their castings to be done in

reliable foundries than to run foundries of their own.

Large Foundries Working on Specialities.—The tendency is for these to increase. There have always been some examples, as in marine, and in locomotive shops, in pump shops, in the manufacture of cast gear wheels, machine tools, cotton spinning machines, agricultural work, and so on, but many others are now added to these. Examples are: makers of lathes alone, of dynamos and motors, some special type of hoisting machine, &c. In such cases the patterns vary but slightly from year to year, all the assistance possible that can be derived from the use of special tackle, and of moulding machines, is utilised, together with the specialisation of the hands. Such shops have no more in common with the jobbing and general shops than the drop forging shops have with the ordinary smithy.

The moulding machines in such shops may be plain, hand-operated entirely, or they may be units in a system, power-operated. The more these increase the more do their adjuncts grow; as conveying, and fettling systems, and subdivisions of tasks, until one man or youth only performs some one section of the work on a mould. The trained moulder is not required in these departments, nor are the men from these departments qualified to work as skilled moulders. A particular branch of machine work is that of moulding gear wheels, which requires a trained moulder, who becomes a specialist at the wheel machine. The ramming and venting are done by hand, as in ordinary moulding. Sweeping boards, and cores are similar to those used in other work. The specialisation lies in the numerous little details essential to the gear wheel moulding.

Iron Foundry.—The shop in which iron castings are produced, either in green sand, dried sand, or loam; together with the core making for them, either by hand or machine methods. It may, therefore, be a very small shop, or a very large one, and embraced in a single building or floor, or in several shops or floor subdivisions. Provisions have to be made for cranes, cupolas, and core stoves; often for tracks, and other plant and machines.

The best main design for a heavy foundry is a brick building, with steel or iron columns carrying girders for an overhead traveller. The columns can be utilised for swinging jib cranes. The best design for a light foundry retains the steel columns and brick walls, but the longitudinal girders are not required, as a traveller is not wanted. Light swinging cranes may be used, in which case the columns afford all the necessary support. Alternative to these, or supplementary thereto, is the system of overhead tracks suspended from beams, or a centre narrow gauge floor track, along which boxes and metal can be run. Or even this may be dispensed with, and ladles be run along on the floor, or carried by hand only in foundries of no great size.

The cupolas and core stoves only affect the design, in the break that they effect in the continuity of the walls. They require small offsets from the main building, with sundry adjuncts, as charging platform, blast pipes, &c., the brick-work of the core ovens, and provision for heating them, &c., which we merely mention now as matters to be remembered in connection with the main design, which has to be slightly modified to include these. Sand-stores are generally located outside the shop.

One of the difficulties in laying out a foundry is to settle the area of the floor, which, while permitting of handling a larger volume of work a few years hence, will not present the appearance of a scantily occupied shop in the present. Herein lies one of the advantages of the system of parallel bays, that it permits of extension without interference with design.

The question of weight turned out per week in a foundry is the proper basis on which to design the lay out, and not the number of men to be employed. Take, say, the case of machine moulding, or of plate moulding, by contrast with the making of small cylinders, say, for portable engines, the larger cylinders for locomotives, the loam made cylinders of marine engines, the toothed wheels of cranes, the valve boxes of pumps, and so on. In the machine and plate moulding departments the amount of work done is out of all proportion to the men engaged, but in the other classes of work named, involving much core making, and coring up, and drying, the labour vastly predominates over the

output. In the first, a large area of floor is covered with a day's work of two or three men. In the second, a similar floor area would be the result of several days' work of perhaps ten times the number of men. The smaller and more intricate the castings, meaning by that generally the more intricate the coring, the higher is the cost of labour. This is reflected in the cost of castings, from the £5 to £6 a ton of fire-bars, railway chairs, kentledge, and similar plain and moderately heavy stuff, to the £15 to £20 a ton for exceptionally intricate and light work.

One may therefore have a large foundry, or foundry area, occupying but few men, but turning out a heavy weekly tonnage; or an equally large foundry or a smaller one crowded with men turning out a very light tonnage in the same period. Extremes may be included beneath one roof, and also all intermediate stages are represented in various works. Area required, and not tonnage, nor number of hands, is therefore the matter to be considered as a working basis.

Floor area may be estimated by the number of casts expected to be made in a week. The dimensions being taken of each separate piece, to these separate dimensions a foot in length and a foot in width may be added to get the average length and width of the moulding boxes and sand space surroundings. Some will be more and others less. Double these dimensions to allow for boxes being laid open during moulding, and add from 1 foot to 2 feet in length and width to permit the men to move about among them. Sometimes there will be middle parts open, making three separate areas. But on the other hand the boxes would never all be open at the same time, some being in course of ramming, others rammed and closed for pouring. All the dimensions thus obtained will then be multiplied by the number cast off each in a week, and added; and the total divided by six to get the daily output. The reason is, that some castings will take a week to mould, of others scores will be made in a day. The several totalled dimensions now being turned into areas will give the floor area required for the actual work of moulding. To this total now must be added the spaces required for tracks, and box storage, areas in front of cupolas, and in front of core stoves.

In reckoning this, the different requirements of different shops and classes of work will have to be taken account of. If loam work predominates, these allowances would be very insufficient, because loam moulds in pieces spread themselves all over the shop, and the area of a finished mould would have to be multiplied by six or eight to arrive at the desirable floor area. In machine moulding, on the contrary, less space would be taken.

Overhead tracks fulfil two functions in foundries. They are used either for hoisting, or for carrying metal, or for both duties. Direct acting pneumatic hoists are suspended from them for lifting. Or the lifting may be done by hoists situated on swinging jibs, and the track be used then only for carrying the metal and boxes, &c., about. A good plan is to have a gang of labourers to distribute the metal from the cupola to the moulders about the shops, and so avoid all that walking about between the cupola and the work which is a common sight in many foundries. This cannot, of course, be done to much advantage where the work is massive, but it can where light castings predominate. Ladles of several hundredweight of metal being run along the tracks, supplies can be poured into hand ladles down the shops. Spill trays located in various places can be utilised to do the pouring over, and prevent getting metal about on the floor.

A typical iron foundry is shown in Fig. 12, Plate I.

Iron Ore.—*See* **Iron.**

Iron Patterns.—*See* **Metal Patterns.**

Isochronous Governor.—This is one that has only one speed consistent with stability. This quality is possessed by the parabolic governor, because as the balls rise, the height of the governor does not vary. Such a governor is thus very sensitive and readily hunts, as do all excessively sensitive governors. To remedy this fault the movements are controlled by springs and by dash-pots, the latter being the better for combating those rapid rising and falling tendencies which arise from the changes of speed that occur during each revolution of an engine, while

springs may be employed to control the general working of such a governor. The spring, exerting an increasing resistance on the increased speed of an engine, causes the balls to press upwards with greater force.

An approximately parabolic governor may be contrived by a suitable proportion and design of the crossed arm governor, the powerful action of which will depend on the relative dimensions, and on the position of the suspension pins and the angularity of the arm.

Designed thus, some governors may be merely very sensitive, but will work without the aid of springs; but others, over parabolised, may be most powerful, and will demand a strong controlling spring. This approximately parabolic governor is known as Farcot's.

The construction of a parabolic governor will be found described in the "Steam Engine" by Rankine. He shows how to design the governor with parabolic cheeks and spring suspended arms so that the balls may move in an absolutely true parabolic curve, and he also shows how, for a close approximation, the point of suspension of a rigid armed governor may be placed on the curvature of such cheeks. The cheeks are of the form of an evolute of a parabola.

The isochronous governor is not a practical instrument in itself, because, since it has only one speed proper to a given height, and its height is the same at all positions, it will move over its full range for any small change in speed, and it has no inherent steadiness, and must have springs. The non-isochronous governor, or static governor, has one speed for a given position, and another speed for any other position, so that as speed varies the governor takes up a different position for each speed, and is said to be static; for if when running at a given speed an external force is caused to raise or lower its height or position, it will return to the position from which it has been forced. It therefore possesses power to adjust itself and to hold a valve gear to a position. If in the crossed arm governor the suspension pins are set wider apart than the ball centres, the balls will drop and not rise when speed increases. Such a governor is over parabolised, if such a term may be employed. A study of this effect helps to the general understanding of the effect of isochronism.

J

Jack.—Jacks are small machines used for lifting or pushing, and operated either by a hand screw, or by hydraulic pressure. Various trade names are given to different types, but the following are the leading kinds, considered as types.

Hand Jacks.—The simplest of these are the *bottle jacks*, so termed because the body is a cylinder of tapering outline, broad on the base, Fig. 13, Plate II. The screw passes through the neck of the bottle, and is turned by a lever inserted in holes in the head. Instead of a plain lever, a ratchet and pawl (double) are frequently substituted, Fig. 14, Plate II. A lever is then inserted in the socket of the ratchet. The body may be a solid cylinder, or of open-sided, tripod form; or a plain three-legged tripod without any cylindrical outline. Jacks of these kinds generally range from 2 tons to 20 tons power. A 2-ton jack will have a $1\frac{1}{2}$-in. screw, and a 20-ton a 3-in.

For use where the horizontal lever would be inconvenient, the *Haley jacks*, and the *windlass jacks* are designed. They both have an iron lever, a permanent fitting, turning in a vertical plane, and actuating the jack screw through gears. In the first named, Fig. 15, Plate II., worm gears are used, the worm wheel forming the nut of the screw; in the second, Fig. 16, Plate II., which shows a double purchase windlass jack, bevel gears are employed. These jacks have feet near the bottom terminating the end of the screw, so that articles can be lifted, though too low down to permit of the insertion of the head of the jack beneath them. Jacks of these types are made with powers of from 2 tons to 16 tons.

Horizontal adjustment is provided for in *traversing jacks*. These are mounted on a base, and traversed thereon by means of a horizontal screw actuated by a ratchet lever, Fig. 17, Plate II. The length of traverse is not great, ranging only from about 7 in. to 12 in. in the smaller and larger powers.

Hydraulic Jacks.—Those in which difference in areas, in combination with a force pump, are made to exert enormous power. Hydraulic jacks were invented by James Tangye, and the first big order came on the launching of the *Great Eastern*, the story of which is graphically told in the autobiography of the younger brother, the late Sir Richard Tangye, "One and All." Fig. 18, Plate II., illustrates a Tangye jack, and Fig. 19 adjacent, the same, in section. In this, A is the force pump, B its plunger actuated by the lever C, and drawing water from the supply in the cistern in which it is enclosed; and which is filled by removing the cover, or through the hole exposed on the removal of the charging screw D. The cylinder E being in its lowest position, the effect of pumping is to raise the cylinder on its ram N, which may go on until the water escapes through the blow hole F, though it should not be continued quite so long. The theoretical gain in pressure is that due to the difference between the area of the force pump and the ram. To lower the jack, the screw G is slackened. The foot H is valuable when an object has to be lifted very near the ground. As the lift is not axial, the foot should not be expected to carry

Fig. 19.—Hydraulic Jack.
(Tangyes, Ltd.)

more than 25 per cent. of the full load which may be taken on the head.

Provided the water used is clean, any water will do; rain, or condensed steam, a little soda being added to the latter. Glycerine must be added in frosty weather. The cistern J is first filled, the cylinder E being in its lowermost position, as shown. The cover K may be removed for the purpose, or the charging screw D be taken out, and the water be poured

Fig. 20.—Youngs' Ship Jack.

through its hole. The lowering screw G is then unscrewed, and the lever C worked up and down a few times. Some water is thus forced by the pump into the space L, and any air present escapes through the valve G into the cistern above, and some water is poured through D to take the place of the air. The function of the screw M in the head is to permit of the escape of any air remaining, for which purpose it is left open to a slight amount. O is the suction valve, spring stopper, and gauze strainer; P the delivery valve, spring, and stopper; Q is a guide key with a screw for alignment of the ram. Jacks of this type are made for loads up to about 60 tons.

Ship Jacks.—These are made for loads up to about 400 tons. Except for differences in arrangement, and in relative proportions of force pump and lifting ram, these are essentially like the common jack. In Fig. 20, A is the force pump, B its ram, operated by the lever C, and actuating the lifting ram D. Owing to the enormous pressure, a safety valve E is sometimes fitted to relieve the ram cylinder of excessive stress. F is the opening screw. The U form of leather is used in preference to the cup leather of Fig. 19. Handles G G are provided for lifting the jack by, H is the suction valve, spring stopper, and gauze strainer, J the delivery ditto.

Pulling Jack.—This, Fig. 21, is an adaptation of the mechanism of the lifting or pushing jack to a pull, its value being apparent in confined spaces

where there is no room for pulley blocks. Here, as before, A is the force pump, B its ram, C the place of attachment of the operating lever, and D the opening or stop-valve. But the main ram E nted by a tube within a tube. r pumped from the cistern F ough the tube out through the to the underside of the piston forms an enlargement of the ıe main tube or ram, and receives the leather packing. The pulling eyes J and K are attached respectively to the cistern end, and to the end of the article to be moved. When in use the tube is drawn out to the required distance, and is then pulled in by pumping. The cylinder L is filled with water through the tube at *b*, the screw being removed for the purpose, and the ram of E pulled out. The stop-valve D is then screwed up, and pumping commences. The valve D is slackened occasionally to allow of escape of air. To lower the jack, slightly unscrew the stop-valve D to permit the liquid which is under pressure in the cylinder L to

Fig. 13.—Bottle Jack.

Fig. 14.—Bottle Jack.

Fig. 15.—Haley Jack.

Fig. 16.—Double Purchase, Windlass Jack.

Fig. 17.—Traversing Jack.

Fig. 18.—Hydraulic Jack.

Group of Jacks. (Tangyes, Ltd.)

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pass back through the cistern F and along the water passages to the top of the piston G through the opening c. The puller can be used in any position, but when horizontally, the cistern end must be kept slightly lower than the opposite end, to facilitate the flow of liquid through the passages into the cistern.

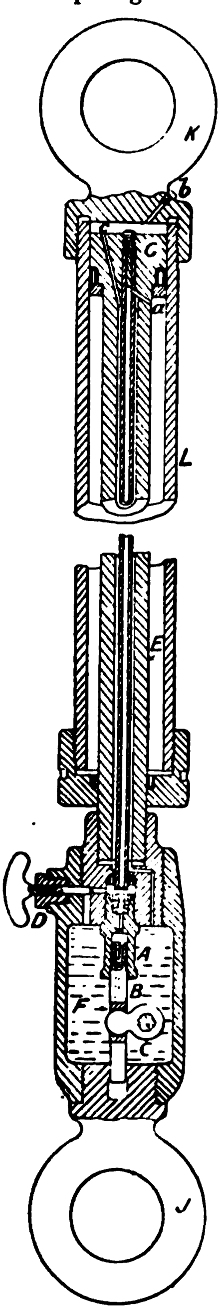


Fig. 21.—Youngs' Pulling Jack.

Jacket, Jacketing.—By a jacket is usually understood a steam jacket, which is an outer casing of some vessel, with a narrow space between the jacket and the inner vessel, in which there is steam for the purpose of keeping the inner vessel hot.

Thus, pans for the boiling of sugar and other substances are fitted with a jacket to furnish the heat necessary to boil the substance in the inner vessel.

In steam-engine work the cylinder is surrounded by a steam jacket, the object of which is to keep the cylinder as hot as the steam that enters it. These were the words of James Watt, and show that he understood the mischievous effects of cylinder condensation. The inner surface of the cylinder is alternately exposed to steam at the temperature of the boiler and at the temperature of the condenser, and the metal of the cylinder endeavours to assume these same temperatures in turn, with the result that the fresh steam which enters the cylinder is partially condensed, and the cylinder is rendered wet, while the wetness thus produced is evaporated by the now heated cylinder when the exhaust port opens, and the pressure of the steam and its temperature falls to that of the condenser. This alternate action is very wasteful of steam and fuel, and in order to reduce this loss, Watt fitted a jacket round the cylinder, and the steam passed through the jacket on its way to the cylinder. This kept the cylinder hot from outside, and such steam as formerly condensed in the cylinder now condensed more or less in the jacket, whence the resulting water was drained away before it entered the working cylinder. This was kept drier, and as there was less water in it there was less heat abstracted by the evaporation of water during expansion and exhaust, and the cylinder temperature not being lowered so much, there was still less tendency to cause initial wetness. The Watt jacket, when carefully drained, is perfectly correct practice, and is never rendered inefficient by the collection in it of air.

Some makers objected to the Watt jacket, and made the jacket distinct with its own steam supply, but undoubtedly such jackets are apt to become choked with air. The best system, but one never attempted, though often advised by the writer, is to have a special higher pressure boiler solely to supply steam for the jackets.

By means of a reducing valve, this boiler and the jackets will be maintained at a higher pressure than the main boilers. All the steam raised by the jacket boiler is thus made to sweep through the jackets and enter the main boilers. The jackets are thus kept clear of air or water; there is no loss of hot water, and the steam eventually reaches the engine cylinder by way of the main boilers.

The old Cornish engineers sometimes built a brick flue or jacket round the cylinder and sent hot flue gas this way, and they even would build a fire under the cylinder to keep it hot.

The benefit of the jacket has been much disputed, but usually, it is to be feared, on the basis of results obtained from jackets which were not known to be properly arranged or even full of steam; and, generally speaking, jackets have given way to superheating, whereby steam is heated beyond its temperature of

formation, and therefore is able to supply heat to the cylinder without itself condensing so seriously. *See* **Superheating**.

The efficiency of the steam jacket must also depend upon the time element, and it is found, as might be expected, that with engines having a high rotational speed, the jacket ceases to be of so much advantage. It has been suggested that jackets might be heated by means of liquids capable of being supplied at a higher temperature than any steam jacket could give, but in this connection it should be remembered that liquids, though heavier than steam, cannot give up so much heat as does steam, because steam in condensing gives up nearly a thousand thermal units per pound without loss of temperature, and a liquid can only give up heat by losing temperature. A liquid-heated jacket is thus not of equal temperature throughout, whereas a steam jacket must be so. Jackets are also made to be filled with water. Such is in effect the outer vessel of the common glue-kettle, which effectually prevents the glue in the inner vessel from becoming hotter than 212° Fahr. at the outside.

The water jacket of the gas engine is a jacket placed outside the working cylinder; its object is solely to maintain the metal of the cylinder and parts at a safe working temperature. The object is not to cool the working fluid, for this is rapidly cooled by expansion and the conversion of heat into work. But the cylinder would acquire too much heat from the burning gas for the piston to run safely. The jacket is very unscientific, from a thermodynamic standpoint, but it is necessary to the safe running of all gas and internal combustion engines. By a suitable arrangement of tank and pipes the water will circulate round the jackets of a gas engine without further aid than its own differential specific gravity due to heat. In large engines water is caused to flow through the piston rods and pistons, and there are jackets round the stuffing boxes, which have rendered the double-acting gas engine possible. But if jackets could possibly be avoided, the efficiency of the internal combustion engine would probably be increased by 50 to 100 per cent., for from a fourth to a third of the heat generated appears in the jacket water. The water jacket of the internal combustion engine is simply a concession to the frailty of our materials of construction and of our lubricating oils. Water jackets are also used upon the cylinders of air compressors in order to absorb the heat which is generated by the compression of air.

The term jacket may properly be applied to the covers used for covering steam pipes in order to prevent loss of heat.

It is to be understood that the action of the steam-engine jacket is to provide heat by condensation of some of the steam within it, so that steam inside the working cylinder may not be condensed.

Condensation is simply transferred from within to without the cylinder. Outside the cylinder it cannot be re-evaporated at the expense of the heat in the cylinder metal, but is allowed to drain back to the boiler by gravity, where this is possible, or it is withdrawn by means of a steam trap. Where the jacket is merely a passage way to the cylinder it is thought by some that it can do no good. This, however, is superficial thinking, due to the confusion between heat and temperature. So long as the jacket is freely in communication with the boiler it may lose heat, but it is impossible that it can lose temperature, since the pressure and temperature of saturated steam are mutually dependent upon each other. It is, however, essential that such jackets should act as separators, or that a separator should come betwixt the jacket and the valve chest in order that the water condensed in the jacket may not get into the cylinder, and effect there the very evils it has been sought to avoid.

Where superheated steam is too hot to be introduced directly into a cylinder, it is possible that very economical working might result by passing it through the jacket, where it will part with its surplus temperature in heating the central part of the cylinder more particularly, to which otherwise superheated steam does not obtain access, seeing that, with safe degrees of superheat, the superheat usually disappears by the time the piston reaches the point of cut-off.

It does not appear that steam turbines have so far been jacketed, and it is difficult to say if a jacket would effect any serious good, but, in the absence of a desire to use much super-

heat among the blades, the passage of the steam through a jacket might be advantageous, especially when turbines are regulated by the system of gust admission, which introduces in the working of the steam turbine the very fault of variation of temperature from which the reciprocating engine suffers.

Jacking-up.—Raising work by means of jacks. Planing the rough surfaces of boards with the jack plane.

Jack-in-the-Box.—The rotating tool-box in the Whitworth double-cutting planing machine.

Jack Plane.—The plane used for removing the outer surface of sawn wood, and for reducing preparatory to the use of a more finely set plane for finishing. The jack plane is about 17 inches long, with an iron $2\frac{1}{4}$ inches wide. Its edge is given more curvature than the iron of any other plane, so that it can cut thick shavings without the corners of the iron digging into the surface of the wood. Sometimes two jack planes are kept on the bench, one for extremely coarse work, and generally with only a single iron, the other to follow it before using the trying or smoothing planes. On some work, of course, only a jack plane is used, but owing to the curvature of the cutting edge the plane marks show, and the surface produced by it does not look well; nor is the plane large enough to make true surfaces as satisfactorily as a trying plane.

Jack Water Pump.—The pump which supplied injection water to the bottom of the cylinder in the old Newcomen engine.

Jag Bolt.—*See* **Bolt.**

Jagging.—The notching of an eye, shaft, or bolt to prevent it from being pulled out of its hole. It is secured by lead, concrete, or by casting in.

Jam Nut.—A **Lock Nut.**

Japan, Japanning.—Signifies the use of protective varnishes, which are dried and hardened by the aid of heat in a closed oven. Black japanning is only one among many varnishes, and there are several ways of producing this, drop ivory black being the best pigment, though lamp-black is used. This may be mixed with shellac varnish, or shellac varnish with resin; or it may be mixed simply with dark coloured animè varnish. Whatever mixture is used, the object is dried in the stove after the application of each coat. From three to six coats may be applied.

Other black grounds are—asphaltum, 1 lb., balsam of capivi, 1 lb., dissolved in sufficient oil of turpentine. The asphaltum is melted over a fire, and the balsam, previously heated, is mixed with it. The mixture is then removed from the fire, and dissolved with turpentine. Or lamp-black is moistened with oil of turpentine, and ground finely with a muller on a stone slab, and mixed with copal varnish. There are numbers of other recipes in which asphaltum is the colouring agent. Coloured japanning is effected by coloured pigments. For brown japan, umber is mixed with the japan. Ordinary painters' colours are used for coloured works, artists' colours for those which are ornamental, ground with linseed oil or turpentine, and mixed with copal or animè varnish. The colours are protected with two or three coats of clear varnish, copal or animè. The temperature for drying ranges from 300° Fahr. upwards.

Japanned surfaces may be polished first with pumice-stone powder, applied with water on flannel, followed with rotten-stone or putty powder and oil, and finally with the dry hand and rotten-stone.

The effect of heating in japanning is to drive off the solvent of the gums or resins in the varnish. The gummy residue becomes semi-liquefied, and adapts itself to inequalities, producing a uniform surface. Firm contact is ensured, and durability.

When metal is japanned it is first simply cleaned and dried. Wood, before japanning, must have its pores filled with whiting and size, which, when dried, is rubbed down with pumice stone. Wood requires less heat, and a longer period in the oven than metal. A suitable priming for woodwork to be japanned is: pale shellac, 2 oz., pale resin, 2 oz., rectified spirit, 1 pint. Two or three coats are applied in a warm dry room. A good black ground is obtained by grinding fine ivory black with a sufficient quantity of shellac dissolved in alcohol on a stone slab with a muller.

Jarrah (*Eucalyptus marginata*).—A valuable Australian timber used by civil engineers for

piles and other maritime works. Large forests of it grow in Western Australia. It has a straight stem, from 40 to 80 ft. high to the first branch, and ranging from 2 ft. to 8 ft. in diameter. The best timber grows on the poorest ground; trees from low-lying lands yield inferior timber. The wood is of a dark red colour, hard, close-grained, fibrous, and resinous. It is said to be almost indestructible, but its principal value lies in its capacity of resistance to the attacks of the *Teredo navalis*, by virtue of a pungent acid which it secretes. Cases have occurred of jarrah having been destroyed by the teredo and the white ants; but on the other hand, the fact has been established that jarrah has remained uninjured in some localities where other timbers have been completely riddled. The average life of jarrah piles in exposed situations may be taken at thirty years. The timber, when seasoned, weighs about 55 lb. per cubic foot. Its transverse strength varies from 500 to 650 lb. per square inch; that is, applied at the middle of a bar 1 in. square, and 1 ft. between the supports. Its crushing strength is about 3 tons per square inch.

Jaw Clutch.—*See* **Claw Clutch.**

Jemmy.—A short crow-bar.

Jenny, or Jinny.—The travelling block carriage of an overhead crane which does not carry operating gears.

Jetty.—A term which is practically synonymous with mole, and pier. It signifies a structure which projects from the shore into the sea, and is utilised for wharfage or landing purposes. It therefore differs from a wharf or quay on the one hand, and from a breakwater on the other, though it fulfils some of the functions of both. A short jetty used for coaling is a staith.

The methods of construction of jetties are those of piers and breakwaters, with concrete in various forms, bag work, blocks, monolithic, and composite work, of piles of timber, and of iron, and of timber frames. The advantage of the latter lies in the freedom of movement allowed to sea currents which pass between the piles and timbers of the frames. Crib work is used in some places, and even when piling is adopted the open spaces are often partly filled up with rubble stone. Mattrasses or fascines of brushwood have been used in Holland, the spaces being filled with rubble.

Jibs.—Crane jibs are either placed horizontally, or set at an angle, and the nature and the intensity of the strains which come on them depend upon their position. They do not fail by crushing, but by cross bending, coming thus under the category of long columns. The struts that sustain horizontal jibs are also columns:—long, short, or of medium length, so that they might fail either by bending or crushing. Ties are in tension, and would fail by simple tearing asunder, or by the failure of an imperfect weld, the eyes being always forged separately from the rods and welded to them.

In the horizontal type of jib which is used when a trolley or jinny is employed for lifting at variable radii, two beams carry two rails for the flanged trolley wheels. Both timber and rolled channel sections are used for these. The outer end is sustained either with a raking strut, or with overhead ties. The self-supporting cantilever jib is used on Titans, or on the Brown, and the hammer types of crane. In the latter examples the cantilevers are frequently double, on opposite sides of the travelling tower. Another self-supporting jib is the Fairbairn, which is a bent cantilever.

With these exceptions crane jibs are of the *raking type*. They are stepped either into the post direct, or into a casting at the base of the post, which may also carry the slewing rollers. The top of the jib is sustained by ties, which are solid rods in non-derricking cranes. For derricking it is necessary to insert a length of chain or rope, while in the true derrick cranes the ties beyond their anchorage at the jib head are wholly composed of chains, to wind round the derricking barrel, and over a guide pulley at the top of the mast.

Raking jibs are single or double. A single solid piece of timber is used in many cranes under about ten tons load, socketed into castings at the foot and head. Two pieces of timber curved in the longitudinal direction, and maintained apart by distance pieces and socketed into castings, are employed on many wharf cranes. Two channel bars or H sections braced together form the jibs for cranes of moderate

power, Fig. 22. Larger ones are built up of plate and angle, and braced—the channel or H sections still being retained, but built up. In others the braced jib is of rectangular section, Fig. 23, being formed of angles at the corners, properly connected with plates at top and bottom, and braced throughout the intermediate length.

These details of construction correspond broadly with the nature and severity of the stresses to which jibs are subjected in working. The main stress is that of compression, the resultant of tensile forces operating through the chain and the ties. But to design a jib to resist compression simply is not enough. The side thrust tending to cripple it by bending sideways is very severe. This occurs because the compressive stress due to the load very often acts, not directly down the longitudinal axis of the jib, but diagonally in relation to it, and this is always the case when the crane is slewing and reversing with a load. If this were not taken account of, a jib would be crippled by side bending immediately. Bending due to direct stress in a vertical plane is less liable to occur, but its risk has to be considered and guarded against.

The single piece of timber is not the form best calculated to resist side stress, since it is no broader at the bottom than at the upper end. Such jibs would fail by breaking off nearer the centre than the ends, hence the reason why they are not made of the same section throughout, but enlarged at the centre and bellied, like two parabolas set together by their broad ends. Timber is not the best material to use in such cases, since a braced structure of the same general outline and of rectangular cross section contains the minimum of material massed wholly away from the neutral axis, with the maximum of strength. This therefore is embodied in the design of the jibs for the heaviest cranes.

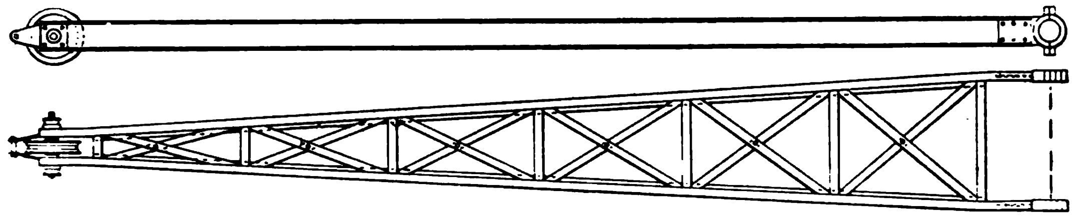


Fig. 22.—Jib formed of Rolled Sections and Bracing.

Between timber, wrought iron, and steel lies the choice of material for jibs. Wrought iron may be regarded now as out of the running—displaced by steel. The writer has seen cast iron used for this member, evidently with the idea that its high compressive strength rendered it eminently adapted for a member in compression. Two castings of an I section formed the jib sides, and they were kept apart at intervals with cast-iron distance pieces. The practice was discarded long since, because it was found that the material though eminently adapted for withstanding a purely compressive stress was not able to sustain the diagonal or cross breaking stresses, and the sudden shocks inseparable from the working of a crane. Moreover the section adopted was one of the weakest possible. The cast-iron jib was in effect in the condition of a long column with rounded ends, in which the compressive stresses were of so unstable a kind that they changed to those of a cross breaking character, stresses which the jib sides were unable to withstand. Further the dead weight of the jib was objectionable for several practical reasons.

Fig. 23.—Jib formed of Angles and Bracing.

The timber jib still holds its own in cranes of many types, but its function has been invaded by iron and steel. The best timber jib is one built up of sides and cross-bars. The single jib is the cheaper and easier to fit, and is quite

suitable for light cranes of no great radius, but the other is much better qualified to withstand side bending stresses in cranes of greater power and long radius. The two beams are arranged to form two sides of an equilateral triangle, with the base at the foot; and the apex—truncated—at the top end. Or the sides, instead of being straight, are bellied, the general triangular outline being preserved. Both these forms of timber jib are good, but the one objection to them is their liability to decay, with consequent diminution of strength. But if care is taken in the selection of and inspection of the material, and its subsequent protection, timber jibs will last for twenty years or longer. The materials mostly used are pitch pine, Memel, red deal, or oak.

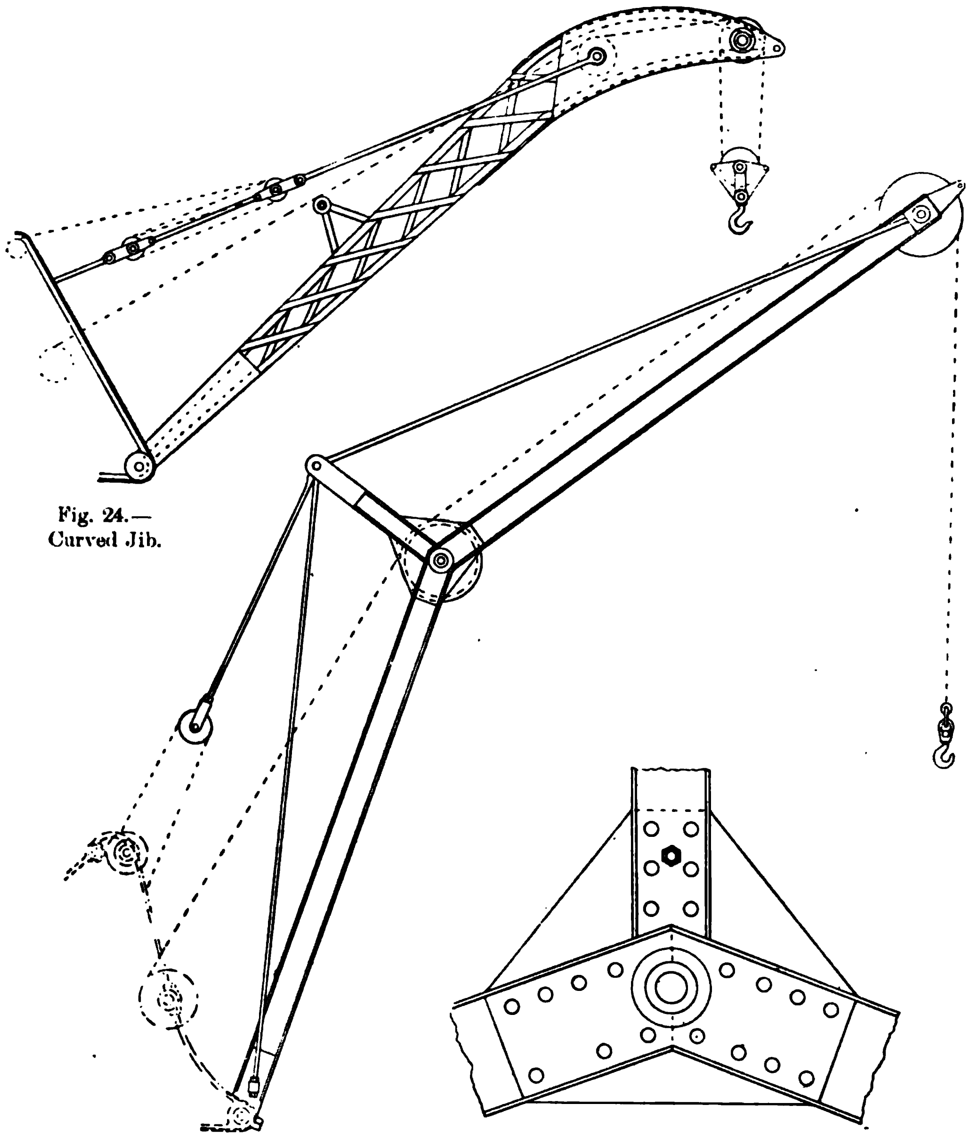


Fig. 24.—Curved Jib.

Fig. 25.—Cranked Jib.

Fig. 26.—Enlarged View of Joint.

The triangular-framed jib in steel is built on

the same general pattern as the timber one, but its sides, Fig. 22, are not cambered. At the base its width is about the same as the distance between the cheeks, while at the top it narrows to receive the lifting pulley. It is made parallel in the vertical direction for convenience of manufacture, its sides being constructed of rolled channels or H sections, or built up with bar and angles to the same sections in the larger cranes. These are sometimes connected with solid webs, but generally with bracing, and often also at the bottom and sometimes at top by their fittings, as timber framed jibs are. Solid webs are only used in the lighter cranes, the additional weight is better left out in long and heavy jibs. The webbing is of $\frac{1}{4}$-in. plates, riveted to angles, which are riveted to the inner faces of the channels or H beams that form the jib sides. In the better class of jibs, and in all those of large dimensions and radius, cross and diagonal bracing unite the sides, also riveted to angles against the sides. In the strongest jibs two sets of bracing are fitted, one against the face of each flange of the side members, making a boxed framing of rectangular cross section, which is the best of all, since it combines lightness with great strength.

Certain cases arise both in derricking and non-derricking cranes in which the jib interferes with the handling of loads of large area, the jib blocking the way as they ascend. In such cases the alternative is to crank, or to camber or curve the jib. Curving a jib, Fig. 24, weakens it, because the metal is no longer in the direct line of thrust, and cranking a jib, Fig. 25, breaks its back at once. The tendency in both cases is to force the jib upwards at the cranked, or bent sections, as though it were hinged thereabouts. Such jibs therefore are rather more costly to make than the straight ones, because of the reinforcements necessary to maintain the strength.

The curved jib, Fig. 24, is self-contained, the necessary extra strength being imparted by enlarging the section at and in the vicinity of the bend, and by anchoring the tie rods there instead of at the extreme end. This is a composite form, since only the portion between the tie-rod anchorage and the foot is in compression, while the shorter length extending beyond to the pulley is a cantilever. Not only are the bent jibs made deeper at the dividing area, but they are plated all over that locality. The side plates receive the castings for the pin that carries the guide pulley, and the tie-rod eyes. These jibs are graceful structures, and many high-class cranes are fitted with them.

In a cranked jib, Fig. 25, each cheek of which is formed of two portions abutted at the plane of set-off, the stress is transmitted to, and sustained by truss rods. The jib becomes a strutted beam; the truss rods are attached to the other end of the strut, and anchored at the jib foot, and at its head. The jib sides and the strut are united with a broad fish plate riveted at the back of each side, and the necessary thickness and rigidity are imparted to the connection by means of cast-iron plates, which are fitted between the flanges of the members. This detail is enlarged in Fig. 26. A casting or forging at the end of the strut receives the pin over which the eyes of the tie rods are fitted.

Jigger.—*See* **Hydraulic Jigger.**

Jigs.—Appliances used to enable work to be tooled accurately and interchangeably, by guiding the cutting tools in rigid paths, or keeping them fixed in a definite position. Also applied to certain fixings which hold work in correct positions to be tooled. The point is that lining-out is not depended on for accuracy, and the time occupied in doing it is saved. Thus in the drilling jig, Fig. 27, the plate is drilled with holes to locate exactly the positions at which the drill will descend and put the holes through the casting beneath. Hardened steel bushes are inserted in the templet to minimise the wearing effect of the revolving drill. The jig is clamped with a couple of clips, or screw clamps, and is set by the outside of the flange. If a central hole has been bored already, it may be used as a means of accurately locating the jig, as in the stuffing box jig, Fig. 28. A similar method is followed when there are two holes adjacent, a spigot standing out from the jig plate in the two places. Drilling and counterboring may be done successively with the same jig, by substituting larger bushes in the holes to accommodate the counterbore diameter. When the jig does not automatically set itself in correct position, it may be located

by centre lines marked on the work, corresponding lines on the jig coinciding therewith. Small lugs are sometimes formed at the jig ends to align with the lines on the work. As it is desirable to alter the position of jigs to suit some classes of castings, small lugs are provided with adjusting screws by which the jig may be moved accurately.

Surfaces at right or other angles are readily dealt with by suitable jigs constructed to fit around the portions, or a piece of work may be entirely enclosed in a box, which is studded with bushes for guiding the various drills to different portions. In such a case all the angles lie correctly, and all the pieces finished

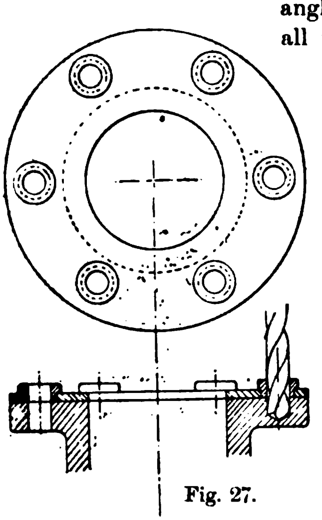


Fig. 27. Jigs.

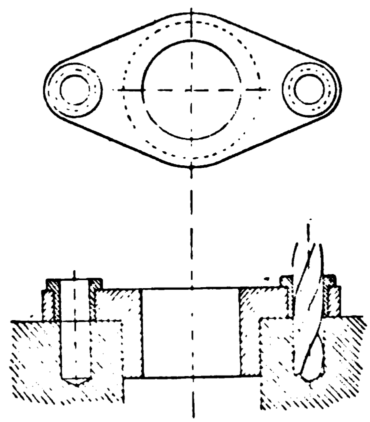


Fig. 28.

are bound to be alike. Hinged parts are fitted to many such boxes, to enable them to be opened to receive the job, and closed upon it.

Jigs for milling are applicable in many cases, their function being to guide the shank of the milling cutter by means of grooves, though much of this work is more properly done on the profiling miller, with plain flat form pieces as guides, controlling a tracer pin actuating the cutter slide. In many jigs there is no attempt to guide the cutter, but the jigs serve as means of presenting the work in certain positions or at various angles. The word fixture is usually applied to these appliances. The object is to provide a fixing into which the pieces of work can be dropped and quickly secured correctly, without involving any tentative setting or testing on the part of the attendant. Planing jigs are also employed for the same function, though to a rather less extent than for milling operations.

Jig Saw.—A machine saw with a vertical reciprocating movement. It is of the fret saw type, but the blade is larger, being about the size of an ordinary bow saw. It is of course much inferior to a band saw in speed, but it has one or two trifling advantages of its own, such as less liability to break, and the possibility of using it if required in place of a hand bow saw, for cutting interior parts. These recommendations, however, are outbalanced by the slow rate at which it cuts, and the band saw is consequently regarded as much superior to it for ordinary work.

Jockey. — Something which is movable, to accommodate varying conditions. Thus a jockey weight is the movable weight on a steel-yard, which by its position keeps the bar or lever in equilibrium under varying conditions of loading. A jockey pulley is a binder or tightening pulley.

Joggle, Joggling.—Signifies generally the fitting of a projection into a recess, to prevent side-slip. A joggle differs from a dowel in being of larger dimensions, generally continuous through a whole length or width. It occurs in timber, in the masonry work of lighthouses, in the fitting of concrete blocks, and of stone facings to concrete masses. The term is also specially applied to the setting down of angles, tees and other sections where they have to pass over portions of other sections or overlapping plates. It is alternative to the use of packing pieces. Where joggling is done in quantity hydraulic machines are used for the purpose. Small quantities are done by the plater at the forge.

John Bull.—The pillar, with its foot and adjustable arm, used in drilling holes with a hand ratchet, or a power-driven drill. It is bolted or clamped down to any portion of a piece of work, and takes the thrust of the drill.

Joinery.—This is distinguished from **Carpentry** in being of a lighter and more neatly finished character, such as is required for interior fittings of all kinds. In house and factory building the joiner makes and fits doors, windows, staircases, handrailing, skirting, and any other wood fixtures that may be required. In public buildings there are counters, screens, seats, desks, cases, and often considerable work on which to lay plaster for ornamental ceilings or to form lanterns, or skylights in the roof. Besides these things which are fixtures, plain articles of furniture come within the province of joinery. In some branches of engineering there is a great deal of joinery, while in others there is none. In shipbuilding, for instance, there is a large amount of interior wood fitting of somewhat similar character to that required in houses. In railway car construction the bulk of the work is done by joiners. Very few joiners have opportunities of becoming proficient in all classes of work. Staircasing and handrailing are generally considered the most difficult, and the latter in its more complex forms is done by specialists.

In modern shops, the joiner is chiefly occupied in putting together parts which have been prepared by machinery. Such articles as doors, and window sashes, when made in large numbers, have their parts prepared entirely by machines, and are glued and cramped on tables provided with blocks, which by a movement of a foot lever and screw compress the parts into position. Mouldings, which are employed to a large extent in joinery, are nearly always worked by machinery except when such a simple form as a bead is required on a part where it can be more conveniently worked by hand. More complex mouldings are sometimes formed by hand planes of the required shape, or by planing each curve and flat separately with ordinary hollows, rounds, and rebates. In joinery, as in carpentry, softwood is chiefly employed, but it must be thoroughly seasoned. In highly finished work, mahogany, teak, and other hardwoods are frequently used. Joinery here merges imperceptibly into cabinetmaking, as at the other extreme it does into carpentry. The methods of the joiner are appropriated in some degree by the pattern-maker.

Joints.—Parts may be held together by screws, nails, or glue, or sometimes by bolts. The pieces to be joined may be made to interlock, as in dovetail and tenon joints; or to overlap, either in themselves, or be overlapped by other parts; or they may merely abut, and be secured by any other convenient means. The best kind of joint to adopt in any given case depends on the form and arrangement of the parts and the purpose which the construction has to serve. Information about **Gluing** will be found under that heading.

The Mortise and Tenon. — This joint is generally the most suitable for uniting the members of framed constructions. In this, a

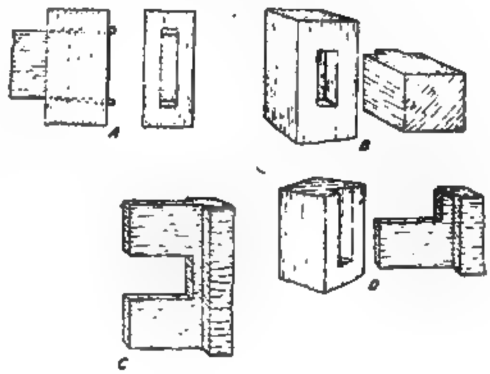


Fig. 29.—Tenoned Joints.

tenon or tongue is formed on the end of one piece, and a slot to fit it is cut in the other. This joint is usually glued, and also secured, either by wedges glued and driven in as in Fig. 29, A, or by wood pins, nails, or screws, put through the parts from one of the sides. There are two main varieties of the tenoned joint. In one the mortise is cut entirely through as in A, and the end of the tenon comes flush with the surface on the other side. In the other, the tenon and mortise only penetrate a short distance, as in B. This latter is known as a *stub*, or *stump* tenon. When sufficiently long it may be pinned from the sides, or wedged by inserting wedges in sawcuts in its end before forcing it home, the wedges then being forced completely in by pressure against the bottom of the mortise. This is called *fox wedging*. But generally the purpose of a stub tenon is more to keep the

parts in position laterally than to hold them directly together, and therefore it is not often they are fox wedged, or pinned, but independent and more substantial means are employed to keep the parts together. Tenons usually measure a third of the thickness of the members. Their width should not be more than about six times their thickness. When the end of the tenoned member is very wide the tenons are divided into pairs, as in Fig. 29, C. The short stump or *haunch* between their roots strengthens and reduces the possibility of the wide piece warping. Where mortises and tenons occur at the corner of a frame, as in Fig. 29, D, a haunch is usually formed, as shown, to allow some amount of material to remain beyond the mortise. Otherwise the joint would be cut through, and must then be secured by pins or screws through the face. For some purposes this latter method is quite suitable. When the members to be tenoned are very thick, double tenons are employed. Another arrangement sometimes necessary is known as a *bareface* tenon. Tenons may also be employed when pieces meet at an angle.

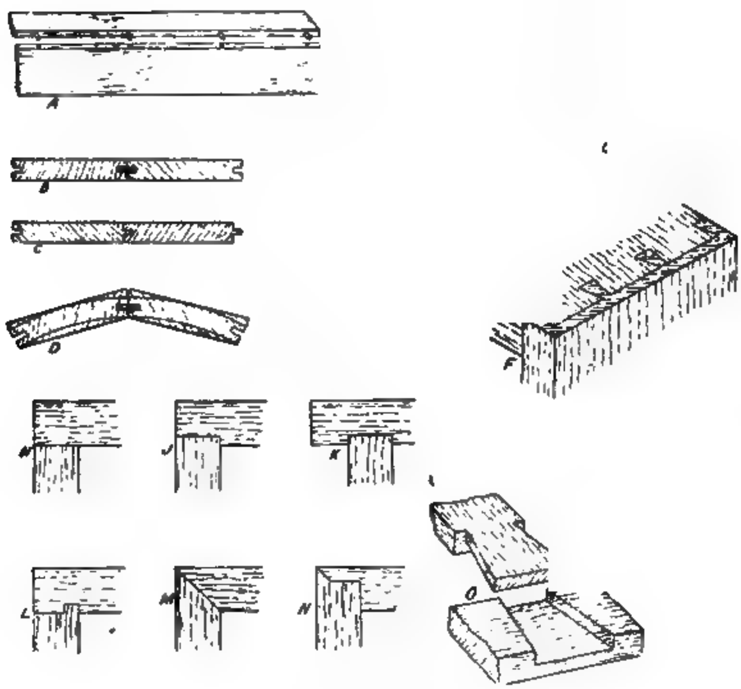


Fig. 30.—Various Joints.

The Dowel.—Dowelled joints are occasionally employed in light work, instead of tenoning, but more frequently they are used in edge joints, as in Fig. 30, A, where tenons would run the wrong way of the grain, and be too weak to be of the slightest value. Dowels are hard-wood pins fitting tightly into holes, and secured also by glue when the parts are permanently joined. The holes made to receive them have to be bored exactly opposite each other in the parts to be united. The dowel is first driven into one portion, and cut off, generally with from 1 in. to 2 in. projecting. The other part is driven on to it.

The Tongue.—Tongued joints are formed by ploughing grooves in a joint and fitting strips in, as in Fig. 30, B. This also is usually employed for edge joints. In match boarding the tongue is worked solid on one piece, as in Fig. 30, C. In wide joints two or more tongues may be inserted running parallel with each other. Tongues may also be used between boards fitted to form a sweep, as in D. Tongues not only keep the surfaces of boards flush with each other, and assist the hold of glue when it is used, but prevent entirely open joints if the wood shrinks.

Lap Joints.—These are usually halved, *see* **Half-Lap Joint.** Pieces may also be joined at an angle to suit a curve to be afterwards worked. These joints are generally held together by screws. They are employed more in pattern-making than joinery. In the latter trade mortises and tenons are generally preferred because they look better and are slightly stronger, while the extra trouble of making them is not much.

Dovetails.—Ordinary forms of dovetails are shown in Fig. 30, E, and F. These are employed for neatly and securely joining wide pieces at right angles as shown, but sometimes when desirable are adopted in cases like Fig. 30, G, where a tenoned or lapped joint might be alternatives. In Fig. 30, E, the end grain of each part is visible when they are together. In Fig. 30, F, known as a lap dovetail, and employed chiefly for drawer fronts, the dovetails are not visible on the front face. In another form the dovetails are concealed on both faces, and the lapping portions beyond them are mitred at the corner. When done by hand, dovetailing takes considerable time, and consequently simpler forms of joints are often employed. Some of these are shown in Fig. 30, H to N.

Abutting Joints.—The simplest and most commonly employed is that in Fig. 30, H, where one piece is nailed or screwed against the end of the other. In Fig. 30, J, a rebate is cut to prevent the shorter piece from getting knocked inwards, the nails alone not being sufficient to ensure absolute immovability. In K it is prevented from being forced in either direction, but the other piece extends beyond to permit of the double-shouldered rebate being formed. Blocks of wood may be attached inside or outside to serve the same purpose as a rebate. In L the outer faces are flush, and a narrow rebate or tongue is formed. Fig. 30, M, shows a plain mitre, and N a stopped mitre. These are difficult joints to secure strongly, and they are used mainly where appearance is of more importance than strength.

Miscellaneous Joints.—Fig. 30, O, is a half-lap joint, dovetailed. In P a short dovetail is employed, and the piece on which the dovetail is formed being much thinner than the other, it is sunk in its entire depth instead of the pieces being equally halved. Fig. 31, A, shows a joint in which pieces crossing are notched slightly into each other to prevent end movement of either. End movement of one only could be prevented by notching that one and leaving the other intact. In the joint at the right hand of A the notching is not carried entirely across the lower member, thus not weakening it so much. This is called a *cogged joint.* In Fig. 31, B, pieces are held end to end by a dovetailed key. An alternative is to cut one of the ends to form the key solid with it, and recess the other one to fit. Another method is to insert a handrail bolt. A halved joint may be made at a corner, appearing as a mitred joint on one face. A slotted mortise and tenon may be mitred on both faces. In Fig. 31, C, a rail is shown notched into a post and held by a bolt, the nut of which is let into a hole cut in one side of the rail, the bolt hole being bored through from the end to meet it. In such cases the hole in

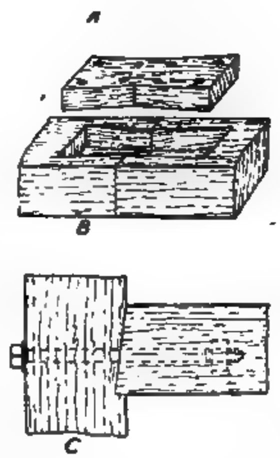


Fig. 31.—Various Joints.

the side is usually plugged after the nut is put in.

The examples given by no means exhaust the varieties of joints possible. The joints of any structure have to be designed to withstand the stresses to which the parts will be subjected. Methods that are suitable in some cases cannot be employed in others. In almost all cases there is a choice of several methods, both of jointing and of arranging the grain of the various parts, and from these the most suitable has to be selected.

Doors.—These are an important class of work in joinery, and are representative of the methods of forming all other large surfaces in wood.

These methods are, roughly, two in number, with minor variations. The simplest is to secure boards edge to edge by means of *cleats*, or ledges, as they are called, as in Fig. 32, A. Diagonal braces are shown in addition, but in the simplest form these would be omitted. In a very rough door the edges of the boards would have plain butt joints, but usually tongued and grooved joints are made, as in Figs. 32, B and C. The edges are beaded, or chamfered, to relieve the plain surface, and avoid the bad appearance of open joints due to shrinkage. When dia-

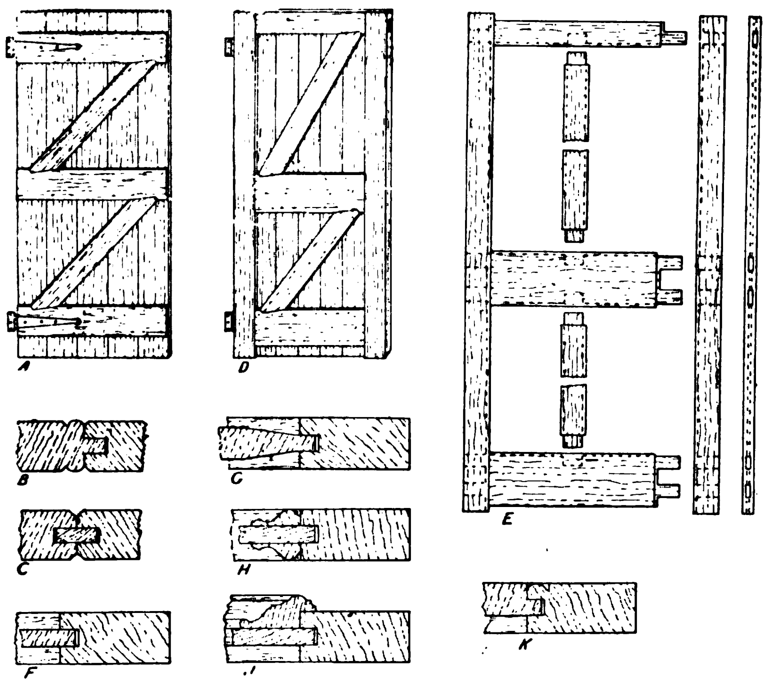


Fig. 32.—Various Door Joints.

gonal braces are added they should slope upwards from the hinges to the outer edge of the door, and are generally notched into the ledges as shown. An improvement on this form of door is to frame it as in Fig. 32, D. The braces, and bottom, and middle ledges are nailed on as before, but the sides and top rail are about twice the thickness, and the boards are tongued into them flush with one face. The ledges are tenoned into the frame with bareface tenons. A door of this type occupies an intermediate position between the simple form shown in Fig. 32, A, and the panelled door in Fig. 32, E, the principles of both being embodied in it.

Panelled Doors.—The panelled door consists of panels fitting in grooves in an unshrinkable frame, the panels themselves being free to vary slightly in width without showing open cracks. The frame in Fig. 32, E, is intended to receive four panels, but there may be from one only to any number, without the principle of construction or forms of joints being affected. The frame is tenoned together as shown, double tenons being formed on wide rails. The inner edges of the frame are ploughed to receive the panel edges, which may fit into it as in Fig. 32, F, or a thicker panel may be tapered down as in G. Moulding bradded to the frame may be put round the panels as in Fig. 32, H, and J, or formed solid on the inner edges of the frame. This latter method is shown in K, where also the panel is shown flush with the frame on one face, as is sometimes done, though usually panels are central as in the other examples.

Door Frames.—These are the wood frames into which the door itself is fitted and hinged. Occasionally they are dispensed with and the door hinged directly to masonry, but, as a rule, a wood frame or lining is first fitted to the masonry. This frame may be solid as in Fig. 33, or consist of thin pieces fitted round the masonry as in Fig. 34, at A. This latter is known as a lining, and when its width is considerable, a skeleton framework called *grounds* is employed instead of solid pieces, which are liable to shrink and crack. This framework is in turn covered by parts tongued and grooved together. A frame in which projecting horns are left on as in Fig. 33 would be built in as

the walls are erected, but more frequently frames are fitted after. To attach them, breeze bricks are built in, or holes bored and plugged to receive nails. The wood should preferably be kept slightly away from the bricks by backing strips. Folding wedges are also often driven between to tighten the frame, but they can only be inserted in places where they cannot bulge the wood. Sometimes the frame is made with a wood sill across the base, but generally it is left open as in Fig. 33, and the lower ends of the jambs are dowelled into stone, or fitted into cast-iron sockets.

Fig. 33. Door Frames. Fig. 34.

Windows.—These, like doors, usually consist of two distinct parts, the sash which contains the glass, and the wood frame into which the sash fits. In ordinary windows, two sashes are made to slide vertically in the frame, the upper one outside of the other with a parting bead between them. Their meeting rails and their bars are made as narrow as possible not to obstruct light. In ordinary sashes the meeting rail is dovetailed instead of tenoned to the stiles, because being shallow it can be jointed more securely in this way. When a tenon is employed, the stile is usually carried 2 or 3 inches beyond to form a horn or bracket, which is useful in wide sashes to assist in keeping them parallel in the frame when they are being raised or lowered. The other rails and bars are tenoned in the ordinary way. When bars cross, the ends of the cut ones are usually fitted to the contour of the other and dowelled or tenoned into it. The glass fits in rebates and is secured by putty or wood fillets. The alternative to sliding sashes is to hinge them. Sliding sashes are usually hung, that is they are balanced by weights within the casing, so that the sash will remain in any position to which it is raised. In the comparatively few instances where they slide horizontally such balancing is, of course, not necessary. The frames for hung sashes have to be boxed up to contain the weights. The connection with these is made by cords which pass over pulleys in the upper part of the frame, and are secured in grooves in the sash. Pockets have to be provided in the lower part of the stiles so that the weights can be got at when required without pulling the frame apart. A parting slip is suspended from the top, but not necessarily fixed anywhere else, to keep the weights from striking each other. The frames for hinged or casement windows do not differ from door frames, and the methods of attaching to the wall opening are similar. In all windows, precautions must be taken to prevent water from driving or penetrating through by capillary attraction. This is accomplished by making throats or grooves at suitable places in the wood, and by inserting metal tongues called water bars between wood and stone sills.

Windows are sometimes provided with shutters. These may be folding or sliding, or of the revolving type, which winds on to a barrel above or below the window. These latter are chiefly of metal, and the joiner's work is only to make what provision may be required for fitting them in place. The sliding and folding types are generally panelled similarly to doors. Those which slide vertically are balanced in the same way as sashes, and recesses provided, generally below the window, for them when not in use. Those which fold consist of a number of leaves hinged together and folding into recesses, or against the wall, at the sides of the window, usually inside the building.

Skylights. — In these there must be no cross-bars to obstruct the flow of water down the glass, and the surface of the rail at the bottom must be recessed so that it supports the glass, but at the same time allows condensed moisture to escape from its under surface. Lantern lights are similar in construction to greenhouses. They stand above the roof surface and are provided with windows in their sides.

Staircases.—The three main types of these are shown in plan in Figs. 35, 36, and 37. Those in Fig. 35 are called *dogleg* stairs. The flights run in opposite directions, and in plan there is no space between them. In Fig. 36 there is a space called a well, and these are

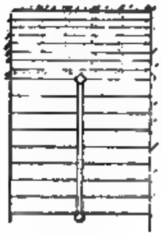


Fig. 35.—Dogleg Stairs.

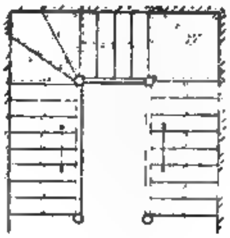


Fig. 36.—Open Newel Stairs.

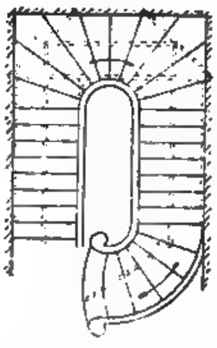


Fig. 37.—Geometric Stairs.

known as open well or open newel stairs. The form of the landings and presence or absence of winding stairs at the turns does not affect this distinguishing feature of the two varieties. In both cases, posts, or newels, as they are called, occur at each change of direction in the stairs and handrail. The other type, shown in Fig. 37, are called *geometrical* stairs, and in these there are no newel posts, but the handrail continues without interruption and without angular turns. These stairs may be of almost any form in plan, but there is always a well. In all types the individual steps are built into inclined timbers called *strings*. Usually they are housed about half an inch into the string which goes against the wall, and the other string is notched to the shape so that the treads and risers which form the steps can be fitted over it. Details are shown in Fig. 38, in which A is the wall string, and B the cut, or open string. Other timbers, called carriages, are often fitted in intermediate positions running parallel with the strings. These give intermediate support to the steps and are useful for attaching laths and plaster to. Straight flights of stairs are generally glued up in the workshop ready to go in place. Other portions generally have to be put together on the spot. Landings are supported by joists from the walls similarly to floors. Strings are either tenoned into newels, or notched and bolted to trimmers or joists of floors and landings. Winding stairs have a separate bearer under each step extending from wall to newel. Cross bearers or carriages are also employed as with straight flights.

Handrailing is supported by newels and balusters, or in geometrical stairs by balusters alone. It follows the inclination of the stairs, rising more rapidly over the narrow ends of winders than over full-width straight ones. It should be several inches higher on the level than it is when inclined. In stairs with newels it is usually in straight lengths, sometimes curved at the ends to raise or lower its height as it reaches a level. In geometrical stairs its curves are complex, as it is required to twist to keep its cross section normal with the stairs while rising, and simultaneously following lateral bends. It is jointed in lengths with plain butt joints, dowelled and held together by handrail bolts.

Joint Board.—*See* **Bottom Board.**

Joist, H-Section, or H-Girder, I-Beam, or Beam, or Rolled Joist.—One of the most valuable forms of beams rolled. They range from about 3 in. in depth, by 1½ in. breadth of flange, to 24 in. by 7½ in. The inner edges of the flanges have from 5° to 8° of angle, or *draft*. Figs. 39 and 40 illustrate the roughing and finishing rolls for joists of 6-in.

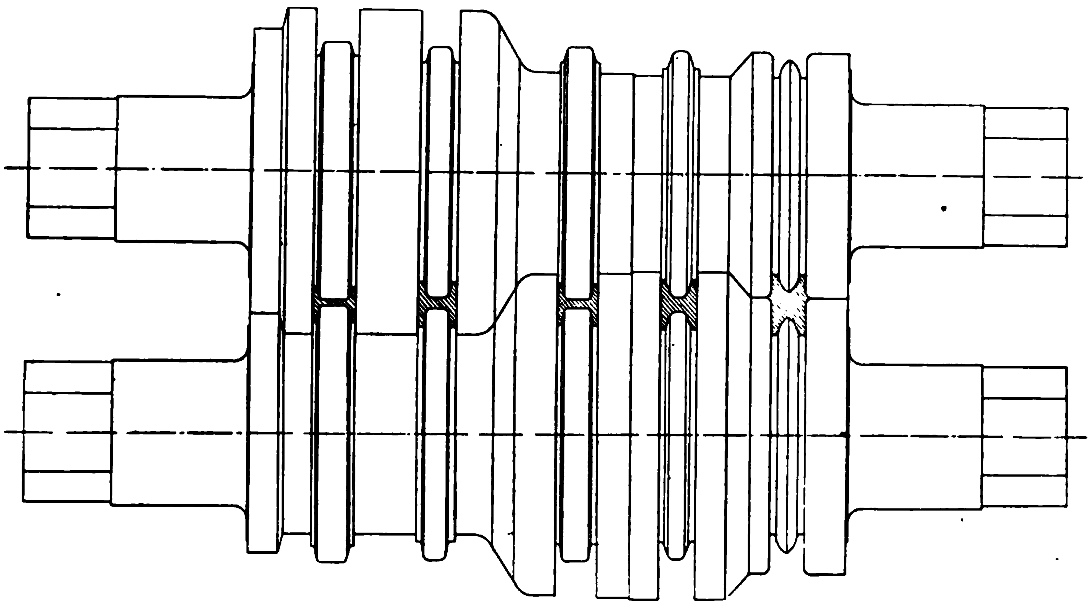


Fig. 39.—Grooved Grain Roughing Rolls, 32-in. Centres, by 6 ft. long, for producing Joists 6 in. by 3 in. by 3 in. (Thos. Perry & Son, Ltd.)

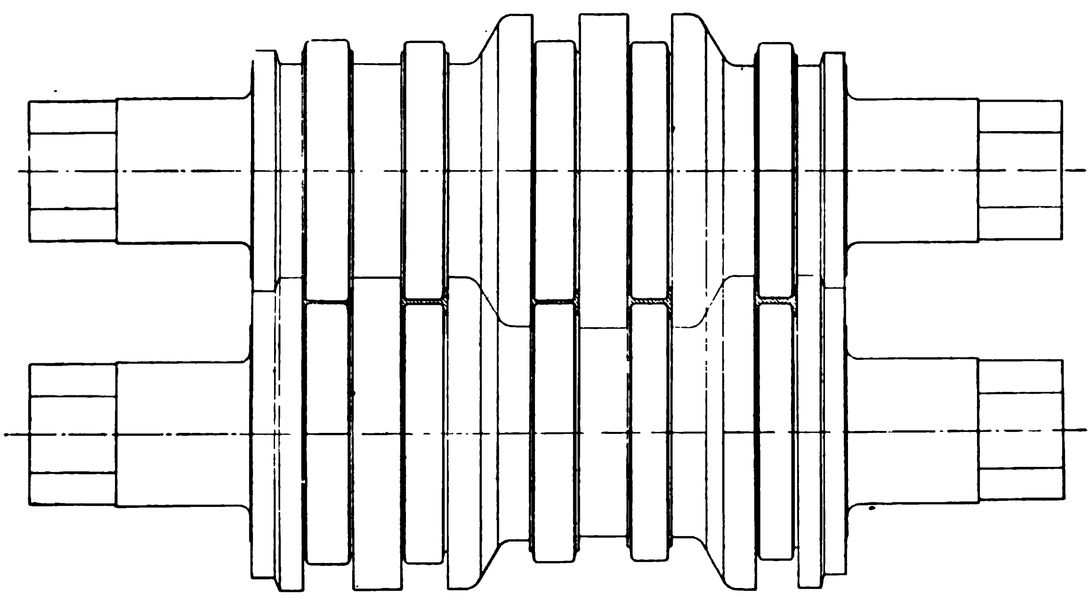


Fig. 40.—Grooved Grain Finishing Rolls, for Joists 6 in. by 3 in. by 3 in. (Thos. Perry & Son, Ltd.)

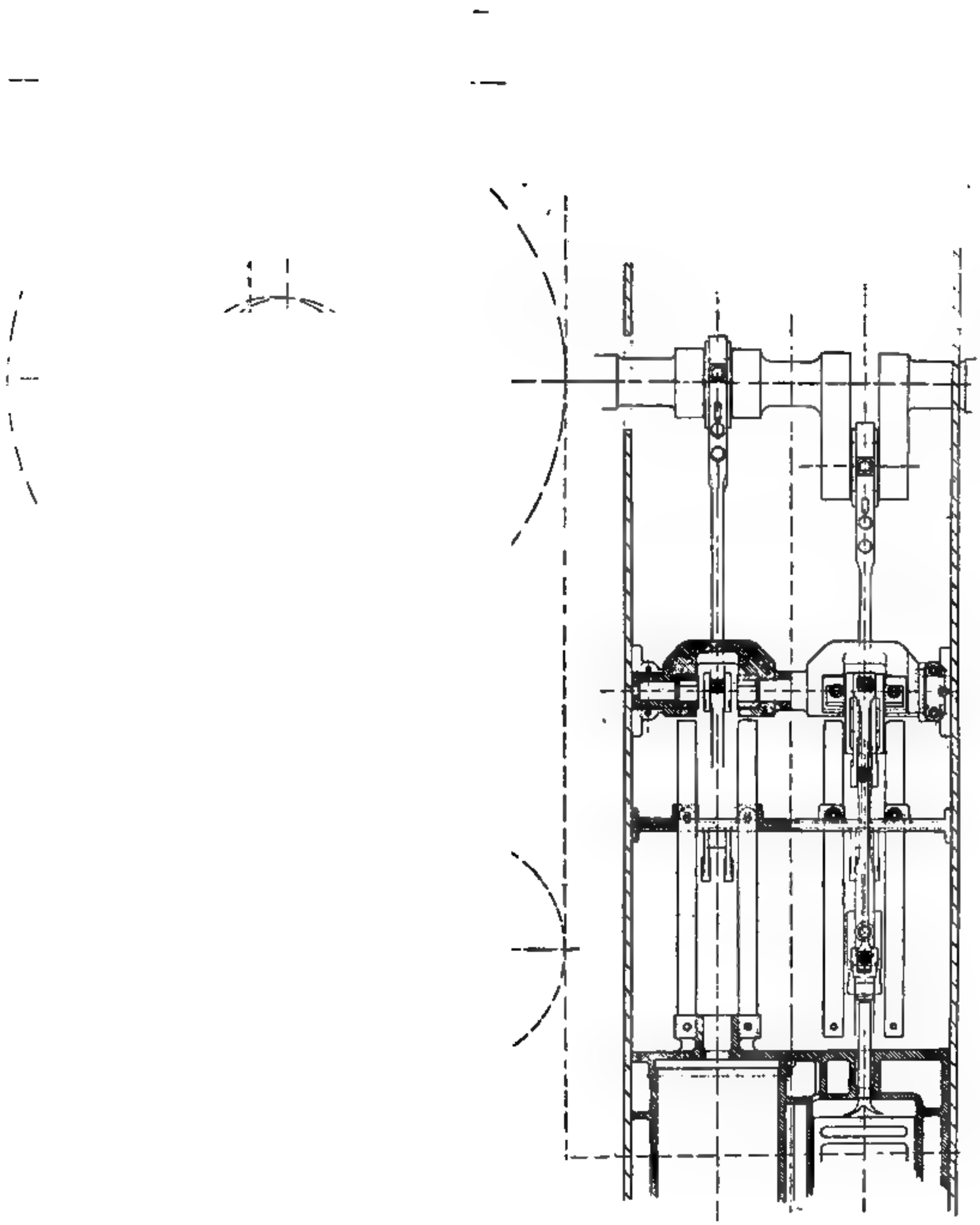


Fig. 41.—Joy's Valve Gear. Lancashire and Yorkshire Railway (G. Hughes, Esq., Locomotive Superintendent).

depth, and 3-in. flanges. The gradual reduction is apparent. Briefly it may be stated thus :— A cogged bloom or slab after some preliminary reduction is entered into the closed passes of the roughing rolls, Fig. 39—the first on the right of the figure. The first pass produces a Gothic furrow on each side, the next a nearly semicircular one, after which the shapes approximate to the H section. In each successive pass the furrows are deepened and widened, and the draft becomes lessened. The vertical dimensions of flanges and web lessen, the width or depth of the section increases, and the radii in the corners are reduced, the joist being finished in the left-hand pass in Fig. 40.

Joists—in Wood.—The term is applied to the timbers on which flooring boards are laid, and to those put up specially for attaching ceiling laths to. The former are called *floor joists*, and the latter *ceiling joists*. Timbers known as trimming joists are also frequently required in floors, and are of larger section than the ordinary floor joists. The latter measure in section about 2 in. by 3 in., and should not span more than 8 ft. to 12 ft. without support. Ceiling joists, having only the ceiling to support, are of less depth. When attached directly to the under edges of the floor joists, 3 in. is usually sufficient. When attached to binders, and consequently only supported at intervals of 8 ft. or 10 ft., they may be 5 in. deep. Generally they are 2 in. thick in either case. Floor joists are never less than 2 in. thick, and seldom less than 9 in. deep. Both floor and ceiling joists are generally spaced about 12 in. apart. The binders of a floor are sometimes called binding joists. Bridging joists is another term for floor joists.

Joule's Law.—Expresses the fact that the quantity of heat produced by friction, if preserved and accurately measured, is always proportional to the quantity of work expended. Experiments were made on the energy of a descending weight rotating paddles in a liquid

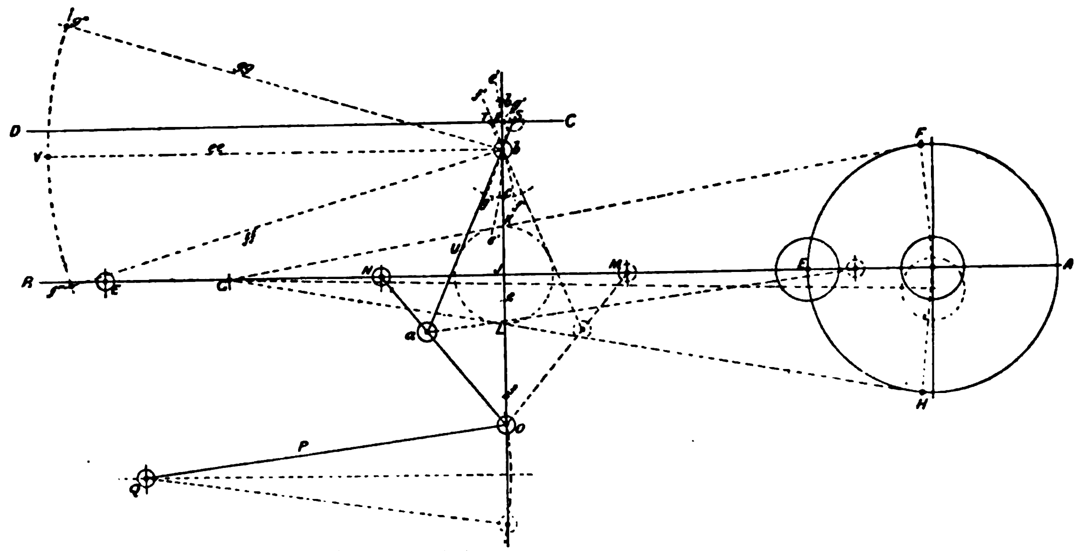


Fig. 42.--Skeleton Diagram of Joy's Gear.

and so raising its temperature. They established the exact relationship between mechanical energy and heat. Joule stated it as the number of units of work in kilogrammetres necessary to raise by 1° Cent. the temperature of 1 kilogram of water. This was 424, the heat unit expressed in metric terms. Expressed in English terms this is equivalent to saying that to raise a pound of water say from 39° Fahr. to 40° Fahr., is equivalent to 772 ft. lb. of work. This is the mechanical equivalent of heat, termed a Joule.

Joy's Valve Gear.—A valve gear named after its inventor, Mr David Joy, and designed to avoid the use of eccentrics. It is used

largely on locomotive engines, notably on those of the Lancashire and Yorkshire Railway, and on some marine engines. The motion is derived from the connecting rod. The amount of opening of the ports is equal at both ends of the valve, and early cut off can be obtained without excessive amounts of lead and early exhausts. It saves space, so that longer crank pins and journals can be used. A working drawing of Joy's gear as used on the engines of the Lancashire and Yorkshire Railway, kindly supplied by the chief mechanical engineer, G. Hughes, Esq., is shown in Fig. 41, and a skeleton diagram in Fig. 42 to serve as a key to the former. The following is a condensed summary of Mr Joy's instructions for laying out the gear, Fig. 42.

Draw the centre line of the cylinder A B, and that of the valve spindle C D; the latter must be in the plane of the vibration of the connecting rod. Draw the circle A E of the crank pin, and the centre lines of the connecting rod F G, H G for the upper and lower positions respectively, with the piston at mid stroke. Take a point J on the centre line of the connecting rod, where its vibration between K and L is equal to about double the length of the full stroke of the valve. It is better to allow rather more than less, in order to avoid too great an angle of the slide link when angled for full forward or backward gear.

Through the point J draw the line K L perpendicular to A B. From J mark off J M, J N, being the extreme positions of the point J on the connecting rod for forward and backward stroke. From M and N draw lines to a point O on the vertical line, so far down that the angle between them shall not exceed 90°, and better if less. These points M N O will represent the centres of the first correcting link A (Fig. 41), pinned to the connecting rod.

The point or pivot O, which will rise and fall with the vibration of the connecting rod, is to be controlled as nearly as possible on the vertical line by a link P—the anchor link B in Fig. 41—pinned either forward near the cylinder, as at Q, or in the other direction. Next, on the centre line of the valve spindle C D, on each side of the centre, set off R S, R T, equal to the lap and lead for the front and back end of the cylinder respectively. Then, assuming the piston to be at the front of the cylinder, and the centres of the connecting rod to be at E E′,—E being the crank pin,—the point to take the motion from will be at N, and the link pinned to the connecting rod for transmitting motion to the valve will be connected at N O (the link A in Fig. 41). From a point on this link which has to be assumed first, say at *a*, which will be about one-third more than the half vibration of the connecting rod, that is, J to K, draw the centre line of the lever U (D in Fig. 41) actuating the valve, that is joining *a* and S.

The point *b* where this point crosses the vertical will be the fulcrum of the lever, and the centre of oscillation of the curved links (C in Fig. 41) in which the blocks which carry the centres of the lever slide. Both centres must be concentric at each end of the stroke.

The function of the link N O, and the attachment of the valve lever to it at *a*, is to eliminate the error in vibration of the lever centre *b*, which would otherwise arise from the arc passed through by the lower end of the lever.

To test if the assumed point *b* be the correct one, mark off the distances *b c*, *b d* (see the diagram, Fig. 42) below and above *b* on the vertical line, so that *c d* is equal to the vibration of the connecting rod on the vertical line, or K L. Then set off the distance N *a* to K *e*, and to L *f*. Then if the length *a b* is applied to *c d* (measuring from *c*) and to *f c* (measuring from *f*), and the point *b* falls below *c d* in each case, it will be necessary to take a point on the lever N O higher than *a*. Or if, on the other hand, *b* falls above *c d*, then a point must be taken on N O lower than *a*.

The point *b* now represents the centre of oscillation for the links (C in Fig. 41 and the fulcrum of the lever D in that figure), and these, as already mentioned, must coincide when the piston is at each end of the stroke, the lead being then fixed, and the links can be pulled over from forward to backward, or to any point of expansion without altering the lead. This is a test always applied when setting the valves.

The point R will be the point of attachment

for the valve spindle link (E in Fig. 41). This may be made of any length, but whatever length is taken, that is used as a radius *e'e'* for the curve of the links, drawn from a centre V on the parallel line *b* V. The angle at which this curve is set from the vertical (which vertical corresponds with midgear) will give forward or backward gear. The angle leaning forward, *f'f'*, towards the front of the engine will give forward gear, that leaning backward, *g'g'*, backward gear. The centres for these curves are at *f'''* and *g''* respectively. The amount of the angle marked on the curve of extreme vibration at *f'* and *g'* will be equal to one-quarter more than the full opening of the port at that angle; so that if 1 in. opening of port be required, then the amount of the angle must be 1¼ in., and the point of cut off will be about 75 per cent.

Jumped Joint.—A butt welded joint, or a butt joint made in belting.

Jumping Up.—*See* **Welding**.

Junction Valve.—A screw-down valve with two, or with three branches. If there are two branches with faces at right angles, the term *angle junction* is applied.

Junk Ring.—Derives its name from a ring which confined the gasket or rope packing formerly used in steam engines and pumps. Its function was to press the packing against the cylinder bore. The term is retained in modern pistons, using metallic packings.

K

Karri, Kari, or **White Gum** (*Eucalyptus diversicolor*).—A West Australian timber, possessing similar characteristics to jarrah, but of a lighter colour, and used for piles and heavy scantlings. The tree grows to a height of from 300 to 400 feet. The timber is hard, heavy, straight-grained, and tough. Though stronger than jarrah, it is not so durable in damp situations. It endures well under water. It is used for street paving, but is liable to split, and to develop star shakes. Its transverse strength is from 650 to 850 tons per square inch, and its crushing strength is 5 tons per inch. Its dry weight is from 53 to 63 lb. per cubic foot.

Kauri Pine, or **Cowrie, Cowdie,** or **New Zealand Pine** (*Dammara australis*).—A tree of the natural order Coniferæ. A light, whitish-brown, or reddish-brown timber of large size. The trees grow to 160 feet high, by from 15 to 20 feet diameter. The wood is easily worked, is stronger than red deal, does not shrink much, and is free from knots. It is used largely in some pattern shops, and by carpenters. Its dry weight is from 30 to 39 lb. per cubic foot.

Keel Blocks.—The blocks upon which a vessel is supported in dry dock while undergoing repairs. As the vessel's keel has to be supported uniformly level to avoid strain, the blocks have provision for vertical adjustment, being made as wedges, and in three parts. The middle piece has extensions by which it is driven in one direction or another. The joint faces are planed, and tongues prevent side slip. The height of a complete keel block ranges from 2 ft. 6 in. to 4 ft. The greater height gives more room for repairs, but requires more depth of water in the dock. The blocks are pitched at from 2 ft. to 5 ft. apart. Cast iron is used for keel blocks; the metal is stout, being about 2 in. thick, and the top block is recessed to receive a piece of greenheart, or teak, or elm planking.

Keelsons.—The saddles upon which marine boilers are supported.

Keep, Keeper.—*See* **Axle Box.**

Keep's Tests.—A series of physical tests which have for their object the rapid and ready determination from a standard size of test bar of the suitability of a cast iron for a definite class of work. Though the grading of iron is approached from the chemical side, Mr Keep has made the physical behaviour of the test bar the means of ascertaining and controlling its chemical composition; and his work has had an abiding influence in foundry practice. The basis of the system is the influence of silicon on the carbon in iron, causing the carbon to pass during cooling from the combined into the graphitic condition, and thus varying shrinkage. Provided the iron contains sufficient total carbon for the silicon to act upon, the quantity of silicon to be added can be varied to produce grades of iron in which any proportions of combined and graphite carbon desired can be obtained. The physical behaviour in the form of a shrinkage test (and not chemical analysis) indicates the results, so that they can be observed by the ordinary foundryman. The point is, that if equal amounts of shrinkage exist in different specimens, then they possess similar qualities as regards strength and hardness; and that the silicon, combined and graphitic carbon, sulphur, phosphorus, and manganese in each specimen are exerting substantially the same influence. The relations between carbon and silicon have been mentioned in the article **Cast Iron,** and the fact stated that it is in graphitic iron that the largest amount of silicon is generally found, and that silicon added to white iron will change the carbon to the graphitic state, in other words will soften it.

Hence the use of silicon as a softener of inferior irons.

But beyond this the value of the shrinkage test lies in the fact, that irons of the same chemical composition will not produce bars of like strength, if they are of different mass dimensions, and also because in different mixtures the chemical elements do not always exert the same influence in bars of the same size. A thin casting, or bar cooling more rapidly than one of larger mass, does not allow so much time for the separation of graphite carbon, and it will therefore be whiter than the larger mass, and will have a greater shrinkage. But added silicon causes graphite to separate more rapidly with resulting greyer iron, and diminished shrinkage. So that a small bar requires more silicon than a larger one, if equal shrinkage is desired, and equal shrinkage of a standard size of test bar indicates that different heats have received their proper proportions of silicon and of other elements. If the shrinkage is too great, add more silicon to bring it back to standard, and *vice versa*. The influence of this element therefore is not direct, but it acts indirectly through carbon. From this central fact this series of tests for foundry use has been elaborated.

The test bars used are small, measuring ½ in. square and 12 in. long and are cast between the ends of a yoke. By passing a graduated taper scale between the end of the test bar and the face of the end of the yoke the amount of shrinkage is measured. As the ends of the test bar are chilled, the depth of chill is measured by breaking off a corner of a bar. Autographic machines are used for testing the transverse strength and deflection by dead load and impact. The reason for using a small bar for relative tests is that, by its rapid cooling, it shows only the influence of silicon in separating graphite. By means of these bars the quality of iron in a cupola can be modified within half an hour. A result is that large quantities of cheap low silicon irons are used, and brought up to the grade required.

Kelvin Balance.—An instrument for the measurement of electric current, designed by Lord Kelvin. A balance beam carries at its ends coils which lie within the influence of other fixed coils placed above and below them. The fixed coils are so wound that a current passing through them tends to pull down one and raise the other of the moving coils, so working the beam. This movement is counterbalanced by an adjustable weight sliding along the beam. As the strength of pull and push on the moving coils depends upon the ampere-turns producing the attracting and repelling power of the fixed coils, the weight is moved along until a point of balance between the opposing forces of coils and weight is found, when an indicator attached to the latter shows upon a scale on the beam the value of the current producing balance. The balance is suitable for measurement of either alternating or direct current, but being an astatic instrument, it requires adjustment to zero each time of use, and, as it is also very delicate and sensitive, is more suitable for laboratory than for workshop use.

Kentledge.—The loose weights supplied with balance cranes, or to any heavy ballasting material.

Kerf.—The width of cut produced by a saw.

Key Boss.—A thickening up of a main boss or hub in a position radially to the key. It should be of the same thickness or a trifle more than that portion of the key which enters into the hub, and there should be as much metal in the boss, measured radially from the key in any direction, as there is measured radially from the bore in the main boss.

Keyhole Saw.—A narrow saw used for cutting sweeps at the bench.

Keying.—The operation of fitting keys and feathers at the hands of the fitter. The keyways in shafts and bores are already cut, and the keys are supplied finished nearly to dimensions by shaping, milling, or grinding, but there is nearly always a little hand work to be done in reducing the key to fit accurately and to drive in sufficiently. The keyways themselves are properly not touched, but all the work is performed on the key, with the file. The first thing is to remove the arris or sharp edge of the keyways left from cutting, and to chamfer or round the angles of the key. It is then tried in, and driven lightly to show on removal the contact spots, which are bright lines. To prevent seizing, oil or chalk is rubbed on the key before driving in ; red lead is also used, and helps to indicate the hard spots, by its rubbing

off where the key presses against the beds. The key is wiped and taken to the vice, and filed on the top with a slanting or sweep motion of the file, to touch off the high spots and impart a generally level surface. Nothing is done to the bottom or sides, unless the latter should happen to fit too tightly; this sometimes occurs when keyways have not been slotted out parallel with the shaft or the bore. A coarse file is used in the early stages of fitting, and a smooth one later; the aim should be to get the top as flat as possible, and to touch practically all over its surface in the key bed. The corners of the key must be kept chamfered as the top is filed, otherwise these keen angles will bear hard in the beds, and make an apparently good and tight fit, which would, however, be spoilt rapidly when the work was put into service, the keen corners getting squeezed down, leaving the key slack. In the case of a key which may project, such as one with a gib head, a certain length should be left standing out for future driving in as the key works slack; if the key is driven in very hard, the length may be less than that allowed when light driving in only is possible, as the chances of its working loose are great.

It is not always easy to remove keys during their trial fittings, especially when the head overhangs the end of the shaft. If there is a clear space at the back of the wheel, into which a key drift (exactly similar to the caulking tool shown in Fig. 137, A, Vol. III.) may be passed to drive out the key, there is no difficulty, but if the rear is blocked, only the head is available. One method is to drive a steel wedge between the head and the wheel boss, using packing if necessary should the wedge be narrower than the gap; another is to insert the claw of a spanner, resting its back against the wheel boss, and jerk the key out by leverage, using a hammer on the end if desired. But the trouble lies in the bending down of the key before it begins to withdraw; the simplest method of preventing, or at least minimising, the bending is to have a helper holding up a heavy sledge hammer beneath the head. Some slight straightening, and trimming of the key head may be necessary during the work.

Feather keys are filed in a similar manner, but more attention is paid to the sides if a sliding fit is given, in order to get the best possible contact all along, and enable the feather to preserve its fit. During the trials the wheel is driven over the shaft and back again, using a mallet, or a block of hard wood and a hammer; or the shaft is driven in and out, with a mallet, or a copper hammer. It is necessary to oil the shaft as well as the key to prevent seizing. Care must be taken to wipe all filings off before the trying in. The method of tentative filing and fitting described above may be largely avoided by taking careful caliperings of the depths of keyway spaces, and reducing the keys to the dimensions at one operation, by filing or grinding, leaving only the slightest amount to come off by filing after one trial.

Keys.—These are employed to connect shafts with their wheels, &c., and cause them to drive positively. There are two methods of fitting, the wedge, and the parallel, the latter being feather keys, which allow of longitudinal sliding of a wheel or clutch. Fig. 43 illustrates the principal kinds of keys. A is the *saddle key*, fitting in a groove in the wheel, but resting only on the surface of the shaft, the drive being therefore frictional. At B a more secure hold is obtained by forming a flat on the shaft. A positive drive is obtained by sinking a portion of the key into the shaft, C, so that slipping round is impossible. The proportions of keys such as C are—Width = one-fourth diameter of shaft; thickness = one-sixth diameter of shaft; taper, three-sixteenths of an inch to the foot. The taper is on the top, the hub being slotted out of parallel to match. The head on the key, used as means of driving in and withdrawing, gives the name *gib-headed* key to C, as distinct from one in which there is no room to put the head, the end of the key then finishing off plain.

A method of keying which is not used so much as formerly, shown at D, and termed *staking on*, is applied to square shafts, eight keys being driven in.

Round keys, E, are employed for some light classes of work, including milling cutters, a hole being cut half-way in the shaft and half-way in the bore, and the pin driven in. It is a simple method, and does not weaken the shaft and bore so much as square-edged grooves—an important consideration in flimsy or delicate work.

A style of key that has grown much in favour, notably among machine tool manufacturers, is

illustrated at F, the Woodruff patent. It is a half-round piece, sunk into a corresponding recess milled in the shaft, with a cutter of suitable diameter fed directly downwards. This method of fitting allows the key to tilt or rock in its seating, so that it may lie with the top face parallel, or tapered, whichever is required. The key projects from its seat by an amount equal to half its thickness. If extra strength is desired, or the length of the wheel bore demands it, two or more keys may be inserted, each in their recess in the shaft. It is claimed as an advantage of this system that the depth of the key prevents it from rolling over in the seats should excessive strain come on. The key has been found to shear clean off, without materially damaging the seats as an ordinary shallow key would do.

Feather keys, G, are sunk into circular-ended recesses in the shaft, and the wheel is forced over, wedging upon the top. Such keys are used where there is no space available to insert or drive the type in C. The other style of feather key, H, has a parallel top, and the wheel slides longitudinally while driving or being driven, the movement being employed to operate sliding gears, clutches, &c., into and out of engagement. As there is no top wedging action to keep the key jammed down, countersunk screws are inserted as shown, two or more in number. Bits of rod are sometimes used instead, screwed in and riveted over. In cases where the wheel or shaft has to slide for a considerable distance it may be more convenient to put the key in the boss, and have a long spline or keyway in the shaft (see J), representing the style of fitting used in the spindles of drilling and milling machines with sliding spindles. The key is held with a stud on its end, or is carried up round to the face of the wheel, sunk therein, and fastened with a screw, K. Two such keys are often fitted, placed on opposite sides to give an equal-sided drive.

Keys are used also to bind flat portions of work together, such as the beds and uprights of boring mills, and similar heavy pieces, the two being tongued together, and a key driven between the tongue and the groove to maintain the fit always tight. Bolts are provided to clamp the portions in the other direction.

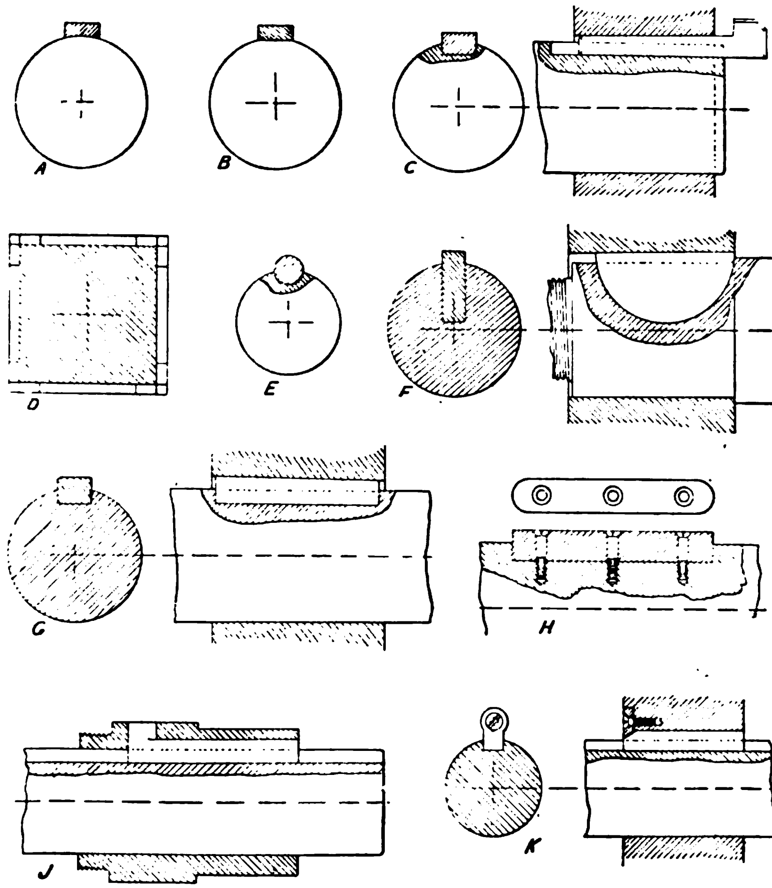


Fig. 43.—Keys.

Keyseating Machines.—Keyways are cut in shafts by the **Slot-Drilling Machines**, or on various types of milling machines, and in bores by the ordinary slotting machine, or with

special keyseaters. It is hardly economical to employ a large slotter on such comparatively light work as key grooving, though such was formerly the usual practice; and a special class of machine has therefore been developed for handling this kind of work, designed on two main lines. In one, a long bar is provided with saw-like teeth, gradually increasing in depth along the length of the bar, this being pulled through the bore so that the teeth successively cut until a groove of the required depth is formed. Machines of this type are constructed in vertical and in horizontal designs. The wheel or other work is supported against a plate or table through which the cutter bar slides.

The other style of machine has a round bar, reciprocated up and down, and carrying a single cutter of the width of the groove. Feed is given to the tool, or to the work, at each reciprocation. In Fig. 44, Plate III., which represents the Colburn machine, the bar is moved up and down through the tee-slotted table by a crank disc beneath, which gives a quick return motion, and a relief movement on the up stroke, to prevent dragging and consequent dulling of the cutter. The feeds are given by the movements of the table, and micrometric screws afford means of setting in the cut with great precision, and also of duplicating depths on repetition jobs. The cutter bar is supported at its upper end by an adjustable arm, carried on a pillar which may be moved into either of three locations on a facing behind the table, the positions being chosen which keep the pillar clear of large wheels with arms, lying in line with the keyway to be slotted. There is no limit to the diameter of work which may be held, since the pillar may stand *within* the rim of a wheel or pulley.

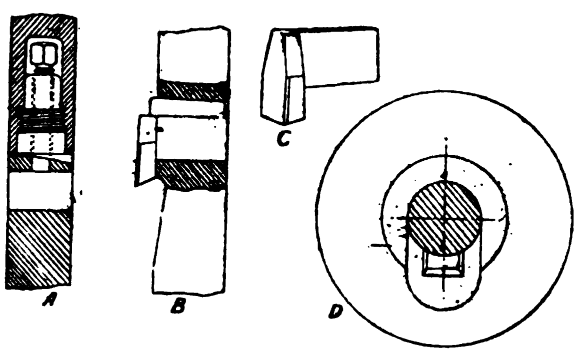


Fig. 45.—Tool Bars for Colburn Keyseater.

The tool bars are constructed as shown in Fig. 45. At A the bar is shown as made in two portions, necessary for the purpose of getting it down through the guide bush in the steady arm. The lower part, which passes up through the table, holds the cutter by a setscrew as shown, and the upper steady portion of the bar is held over the end by a screw fitting combined with two plain diameters, affording perfect rigidity. On the larger sizes of the machines the arm has a guide bearing which is divided and opened with a hinge, enabling the bar to be clasped; it is then made all in one piece, and the cutter is secured with a wedge, B. A cutter is shown at C. One of the chief advantages of these keyseaters is that the work is chucked by the bore, which instantly sets the piece in correct position. The method is to use centring bushes, D, attached to a plate on the table, and having a slot at one side to allow the cutter to operate on the encircling bore. The appearance in plan is as shown. It is not essential that the hub of the wheel be faced; by employing an extra long bushing, the bore alone holds the piece true and square.

Attachments are made for doing special work, such as key slotting, rack cutting, internal gear slotting, with the help of a rotary table. Very narrow slots or cotterways may be tackled by using a special flat cutter bar. The table tilts in two directions for taper keyway cutting, the amount per foot being shown by graduations.

Fig. 46 gives a sectional view of a different kind of machine, having no upper support for the bar, an equivalent result being obtained by fixing the cutter in a long bar, A, and supporting it, through the medium of a wedge B in a grooved bar C standing up from the table E of the machine. The work is held with bushings as in the other type previously described, and the cuttings fall through the table and out by the shute F. The cutter bar

Fig. 44.—Colborn Key-seater.

Fig. 76.—Valve Chuck. (A. Herbert, Ltd.)

Fig. 77.—Valve Chuck in Operation. (A. Herbert, Ltd.)

To face page 52.

A is driven up and down through the rack and pinion G and H, reversed by friction cones standing off a little way from the machine base. The whole mechanism in front of the rack H slides up and down between guideways in the framing. The cutter feed is put on by moving the block J through a handle connected with a screw (not shown) causing J to draw down the thin strip D attached to the wedge B, and making the latter push the cutter outwards, this being repeated at each stroke. The bar is attached at its bottom end in a block that

Fig. 46.—Keyseating Machine. (Mitts & Merrill.)

possesses a slight amount of vertical motion, which comes into play on the upward non-cutting stroke, letting the cutter drop slightly, and fall back from the work, to afford relief. A spring below K cushions the bar when it drops. The smallest bars are made in one with their cutters, but the larger ones have tapered dovetail grooves at the top (see the enlarged detail, L), into which the dovetailed backs of the cutters wedge themselves.

Kick Stamp.—*See* **Belt Drop Hammer.**

Kieselguhr.—*See* **Dynamite.**

Killing.—Adding zinc to hydrochloric acid, so forming a chloride of zinc—killed spirits—used as a flux in soldering.

Kilowatt.—The unit of electric power, equal to 1,000 watts, 1·34 HP., or 43,032 foot pounds of mechanical energy.

Kilowatt Hour.—The Board of Trade unit of electricity, representing 1,000 watts applied for 1 hour. Thus:—

$$\left.\begin{array}{l}1{,}000 \text{ watts} \times 1 \text{ hour,}\\ 500 \text{ watts} \times 2 \text{ hours,}\\ 250 \text{ watts} \times 4 \text{ hours, or}\\ 2{,}000 \text{ watts} \times \frac{1}{2} \text{ hour,}\end{array}\right\} = 1 \text{ K.W. hour or 1 B.T.U.}$$

See also **Board of Trade Unit.**

Kinematics.—Used in the same sense as **Dynamics.**

Kinetic Energy.—Sometimes called "vis viva" or "living force," is the form of energy possessed by a body by virtue of its motion, and which it can give out as mechanical work in coming to rest. A falling drop hammer is possessed of kinetic energy; when raised and motionless the energy is said to be "potential." The energy of waterfalls may be similarly regarded as potential and kinetic—the greater the volume and height, the greater the energy available.

If the weight of a raised body in pounds be represented by W and it falls from a height h feet, its potential energy = Wh foot pounds, and at the end of its fall this potential energy, Wh, will be lost. The velocity at the end of the fall will be $v = \sqrt{2gh}$; from this, $\sqrt{h} = \frac{v}{\sqrt{2g}}$ or $h = \frac{v^2}{2g}$. So that the potential energy which is lost, Wh, is shown to equal $\frac{Wv^2}{2g}$; that is, the kinetic energy of a body in foot pounds or the total amount of work it will do against resistance in coming to rest =

$$\text{wt. of body in lb.} \times \frac{\text{sq. of its velocity in ft. per sec.}}{2g - (64{\cdot}4)}.$$

For example, suppose it be required to calculate the kinetic energy in foot tons of a train of 200 tons moving at 30 miles an hour (30 miles per hour = 44 feet per second).

$$\text{Kinetic energy} = \frac{200 \times 44 \times 44}{64{\cdot}4} = 6{,}012 \text{ foot tons.}$$

Kinetic Friction.—*See* **Coefficient of Friction.**

King Post.—The central vertical member of a trussed frame. It is subjected to tensional stress, its upper part being sustained by inclined members, and its lower part attached to and sustaining the middle part of a beam. It is

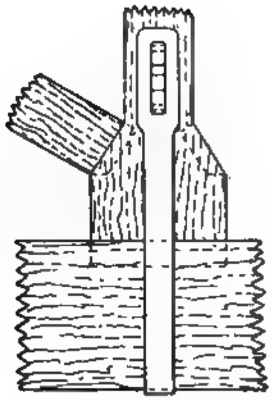


Fig. 47.—King Post.

frequently employed in roof trusses. The usual form of the post, and methods of attachment are shown in the illustration, Fig. 47. Its width at top and bottom is about twice that of the middle part, to provide the necessary abutments for the sustaining members at the top, and generally also for struts from the bottom. The post is generally of wood, because that material is very suitable for notching to the required shape. When metal is used instead, it takes the form of a round iron rod, and is called a king bolt. For supporting the tie-beam of a roof truss, a stirrup tightened by folding wedges through the post is the strongest method. In small trusses a bolt is often used instead of a stirrup, the nut being let into the post from one side and the hole plugged, and the bolt going through the tie-beam and up the centre of the post to meet the nut. The post is also stub-tenoned into the beam, and the other members are stub-tenoned into the post. At the top a wrought-iron strap is usually bolted across the post and the members united to it, the thickness of all being made uniform. Straps are also often used across the struts and post at the base. In a roof truss the top of the post is slotted to receive the ridge plate. Sometimes the base of the post and the struts are held in position by a casting made to receive them.

Kingston Valve.—One of the sea valves or cocks in a ship's side, the function of which is to supply suction to the circulating pumps, and to discharge the boiler blow-off. The valves are made to close automatically in the event of fracture of the spindle, the seating being the frustum of a cone, tapered to about 8 in. in 12. The mouth is closed by a grid or grating, having an area of openings larger than that of the valve. The valve is of brass, and the body either of iron or brass. There are differences in design.

King Truss.—A triangular frame tied by a central king post or king bolt, one end of which is secured to the apex of the triangle, and the other to the middle portion of the opposite member. The post or bolt is thus in tension, and provision is made for tightening it if required. The truss is intended to stand with the post in a vertical position, and the main function of the latter is to support the middle part of the horizontal member at the base. Usually also a king truss has struts

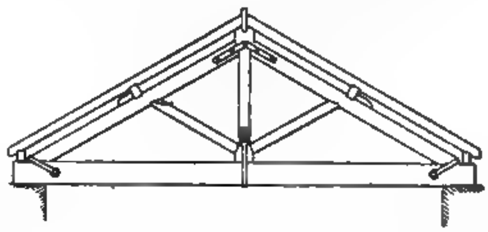


Fig. 48.—King Truss.

springing from the base of the post to support the middle part of the two inclined members of the frame, so that all three sides of the triangle receive support at points half-way in their length. The apex of the triangle may also be made to support the central part of a beam above it.

The king truss, or king-post truss, as used for roofs, is shown in Fig. 48. The tie-beam and the rafters receive support in the middle of their length. The trusses bridge across the building at intervals of 8 or 10 feet, and are connected by transverse members on which the common rafters are laid. The latter, which are only about 12 in. apart, are thus afforded support in the middle of their length by the transverse rail called a purlin, which is placed immediately over the struts. When a roof is so large that the common rafters require support at two or more intermediate points in their length, other forms of truss with the requisite number of internal struts are employed in preference to a king truss with only one pair of struts. The lower ends of the principal rafters need to be well secured to the tie-beam by tenons and notches, and held also by straps or bolts, or in very heavy trusses, fitted into cast-iron shoes on the beam. Tie-beam, king post, and principal rafters are generally of similar thickness. In a small truss this is generally 3 in., and in a large one of 30 ft. span, 5 in. The depth of the tie-beam is generally about twice its thickness; the principal rafters a little less; the king post and struts about square in section. The king post and tie-beam are in tension and the other members in compression, this being slightly complicated in the case of the tie-beam and rafters by a tendency to bend or sag down in the unsupported parts.

King trusses are frequently introduced in compound roofs, sometimes as the main element, sometimes of secondary importance, as when placed above the straining beam of a queen-post truss. King trusses are frequently constructed entirely of iron, or with tension members of iron and the others of wood, but the principle is always the same.

Kink.—An abrupt bend or twist in a piece of metal or in a chain.

Kish.—The scum which rises from grey iron in a foundry ladle, consisting largely of flakes of graphite.

Knee.—An elbow pipe, or a pipe the two branches of which meet at a sharp angle. Also a bracket of timber or iron which connects two pieces of work at an angle.

Knife Edge.—A keen edge of steel employed as a bearing for levers.

Knife Tool.—A tool used by turners in common, and in turret lathes. It has a plain, straight, knife-like cutting edge, instead of a round nose. It finishes square up into a corner, and thus avoids changing a roughing tool for a finishing. Though it does not take a coarse traverse feed, it is able to cut broadly, so that the net result is good.

Knotting.—A compound used for covering knots to prevent them from absorbing paint. It is composed either of shellac varnish or of red lead and size.

Knuckle Gears.—An understanding of the principle underlying the **Lantern Gear** will enable us to relegate the knuckle gears in Fig. 49 to their proper class. Each of these is a disguised lantern gear. In Fig. 49, A, we have what is termed a knuckle gear, and this, if correctly struck out, is really the action of two lantern wheels, or wheels with *pins* only. This is clear from the dotted lines which complete the pin circles. But then, strictly speaking, it is no scientific gear at all, because the very essential upon which the lantern gear is based, namely the cycloidal *face*, is cut away, so that though the cycloidal action may be supposed to commence at the pitch line, it ceases immediately. Yet, though faulty in design, these knuckle gears are popular with some crane makers, because their action is equable and easy. It is not difficult to see the reason of this. There is no oblique thrust worth mentioning. The thrust takes place only at the pitch line, and at a very little above and below it, and is there-

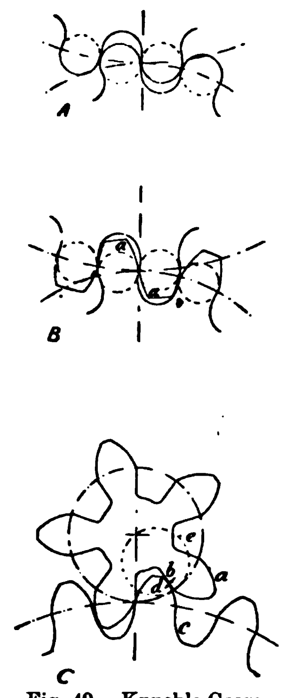


Fig. 49.—Knuckle Gears.

fore practically normal to the line of centres. The absence of angular faces prevents the friction which is so injurious in badly formed cycloidal gears.

In Fig. 49, B, we have a case of a modified kind. The faces of the wheels are each struck with a rolling circle equal in diameter to the pitch diameter of the other wheel. Consequently the *hypo*-cycloids in each case are *points*, and the only legitimate gear would be with trundles. But since both wheels have tooth faces, this is impossible, hence the flanks of each are cut for clearance only; that is, they are cut to the contour which the most projecting corner *a* of the face would cut out for itself. Now this does not constitute a true gear, since it is obvious that contact only occurs along the pitch line. Actually it takes place over a larger area immediately the wheels begin to wear, and wheels struck like these work well for many years. But in principle they are not good. The more legitimate use of this principle is to be found in such a gear as Fig. 49, C, where it is desired to obtain a pinion with a very small number of teeth in order to gain power without intermediate gear. Here the pinion faces *a* are struck with a generating circle equal to the diameter of the wheel; and the flanks *c* are cut simply to clear the faces *a*, as in the last example. There is therefore no true gear between *a* and *c*. But *b* and *d* may be made to gear absolutely correctly, by striking them with a circle, *e*, equal in diameter to the radius of the pinion.

Knurling Tools.—Small hardened steel rollers, formed with various cross-hatchings or other patterns upon their peripheries. They are mounted in holders, to revolve freely, and presented to the surface of revolving work in the lathe, the result being that the work receives the impression of the knurl, and is thus roughened suitably to afford a secure grip for the fingers, or to feed various articles along. The tools are used both in ordinary lathes, and in the screw machines. Some knurls are made with two rolls, held in a hinged portion, so that they accommodate themselves to the work. Lengths exceeding the width of the rolls are knurled by traversing the tools laterally. The operation is also termed milling.

Kyanizing.—The preservation of timber, effected by impregnating it with corrosive sublimate or chloride of mercury. About 1 lb. of sublimate to 10 gallons of water produces a mixture of maximum strength. Twenty-four hours per inch of thickness are required for impregnation. Kyanizing is more costly than creosoting, and is employed where wood has to be painted, or where there is risk of fire.

L

Lacquer, or **Lacker**.—A varnish composed of shellac and spirits of wine, in the proportions of about ½ lb. of pale shellac to 1 gallon of spirit. The solution is made without heat, which would give it a thick appearance, but frequent agitation is necessary to dissolve it. After the mixture is made it is left to stand until the thicker portions are precipitated, when the clear part is poured off, and kept in a bottle away from light, which would darken the tint. Pale, or orange shellacs are used for light coloured lacquers, and the darker coloured seed-lac for darker tints.

Lacquers are coloured with turmeric, Cape aloes, saffron, or gamboge when yellow tints are wanted. For a pale yellow, 1 oz. of gamboge, and 2 oz. of Cape aloes, powdered, are mixed with 1 lb. of shellac. For a deep yellow, ½ lb. of turmeric, and 2 oz. of gamboge to the lb. of shellac. For a red lacquer, ½ lb. of dragon's blood, and 1 lb. of annatto may be added. A pale gold coloured lacquer is made with 8 oz. of shellac, 2 oz. of sandarac, 8 oz. of turmeric, and 2 oz. of annatto to 1 gallon of spirits of wine. Instead of mixing the ingredients together, a saturated solution is made of each of the colouring matters separately, and adding either as required to the pale lacquer.

Metals and alloys used in model work are lacquered by brushing the liquid lacquer over the surfaces with a camel-hair brush. The articles should always be warmed first to a temperature too high to permit of holding them in the hands, or about that of boiling water. The lacquer lays better on a hot surface, and dries more quickly, and does not appear cloudy. A flat hot-plate affords the best method of heating. Any grease or dirt present must be removed entirely, or the lacquer will not adhere. Two or three strokes of the brush are sufficient, and two coats of lacquer, but the second may be applied immediately following the first. The heat, thickening the lacquer in the brush, causes streaks unless fresh lacquer is taken up frequently, or care is taken to dip the brush occasionally in spirits of wine as a thinner.

Ladder Dredger.—*See* **Dredger**.

Ladle.—*See* **Casting Ladle**.

Lag.—The angle of displacement of the phases in the sine-wave of multiphase currents of electricity. *See* **Alternating Currents**.

The cosine ϕ is the sign of this angle and varies according to the value of the self-induction. It is calculated from the ratio of the *real* and *apparent* watts, and as the self-induction causing lag is a source of loss, cos $\phi =$ the power factor of the circuit. With an inductionless load it is unity. With an inductive load it may be, say, ·9, when:

Volts × Amps. × ·9 = real power in the circuit. *See also* **Wattmeters**.

Lag, in coppersmithing is the flanging inwards of the end of a cylindrical body.

Lagging, or **Cleading**, or **Clothing**.—Signifies the practice of covering engine cylinders, and some steam boilers—locomotives and vertical ones chiefly—with a casing of steel sheet, or of wood, with a non-conducting layer between the casing and the boiler.

Before any lagging can be done, provision must be made for openings for the various parts of the boiler or cylinder that stand out from the body. Manholes, fire-doors, &c., must be encircled, and seatings for cocks must be attached to the shell to bring the cocks outside the casings. In the case of the angle rings, the flat flanges rest upon, and are screwed to the faces of the lagging strips.

Wood Lagging.—This is fitted in narrow strips, Fig. 50, tongued and grooved like matchboarding, but frequently the strips are grooved only, and the tonguing consists of strips of hoop iron inserted therein. The strips are narrow, from 2½ in. to 3 in. wide, by ½ in. thick, of mahogany, or of pine. The joints break with a plain bead on one edge for good appearance, and to save

the trouble of having to dress off joints perfectly flush. The strips are screwed on hoops of ash which encircle the boiler, bent either by saw kerfing, or by steaming. The cross section of the timber ranges from $1\frac{1}{4}$ in. to 2 in. square, and the hoops may be set about 2 ft. apart. If saw kerfed, wedge-shaped pieces are cut out, as at A, Fig. 50, and this is sufficient to permit of bending round. The ends of the ring must overlap by about a foot, one end rising up

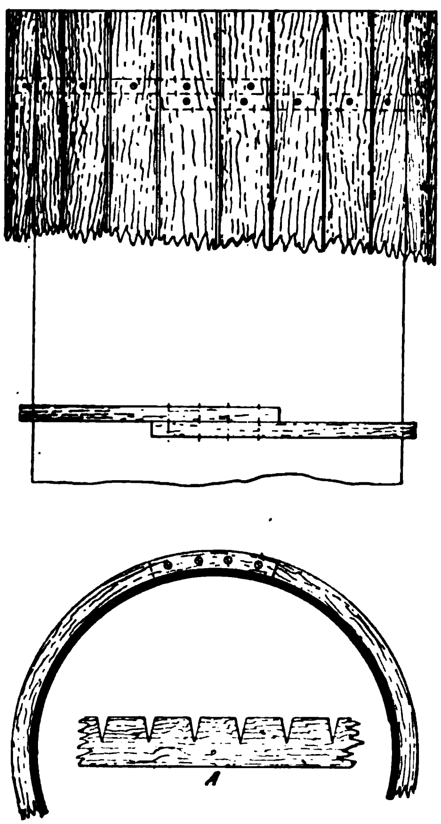


Fig. 50.—Lagging Strips and Hoops.

over the other, in which position they are clamped and secured by three or four wood screws, Fig. 50. If steaming is resorted to, the saw kerfing is not necessary. The lagging strips are inserted in a box into which steam is turned for about an hour. They are then bent round an iron ring of the same diameter as the outside of the boiler, and cramped and wedged, and the ends screwed together, Fig. 51. When cold they retain their shape, and can be put round the boiler, the ends being unscrewed first and the screws re-inserted afterwards.

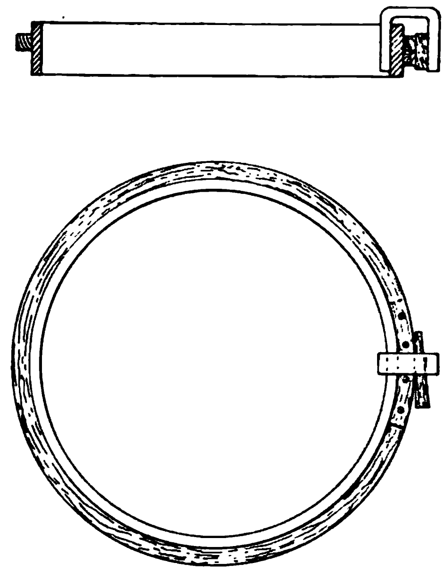


Fig. 51.—Bending Hoops.

As boiler rings differ in diameter by twice the thickness of the plates, the wooden rings that go round the belts of smaller diameter have

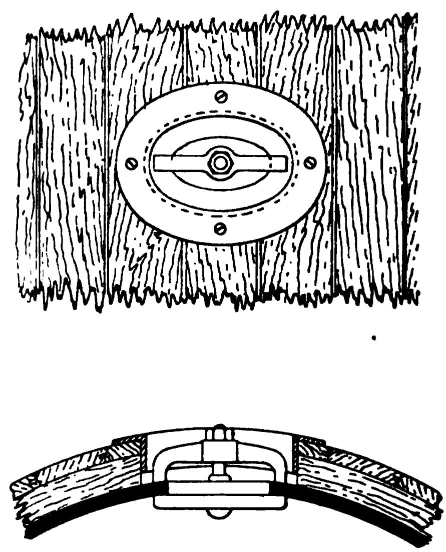


Fig. 52.—Fitting Angle Ring.

to be of thicker stuff than the others, by the thickness of the boiler plates.

The spaces between the rings are filled with

felt, or other non-conducting material, and the strips are retained in place with fine wire during the fitting of the strips. The strips are fitted singly, and screwed into the belts, one screw in each belt. Many have to be cut off where the angle rings and seatings block the way, and are cut to fit against these. In some localities where they are thus shortened, support is afforded by short sweeped pieces fitted to the boiler to receive screws put through the lagging. The iron angle rings also receive screws which pass through the flange into the lagging, Fig. 52.

It is usual to bond wood, and essential to do so when iron lagging is used. The bonds are of hoop iron, or of brass, and receive angles, or

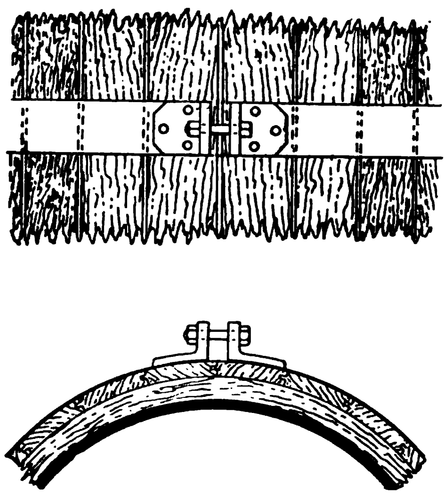


Fig. 53.—Bonding Lagging.

light angular forgings riveted on to receive the tightening bolt, Fig. 53.

Sheet-iron Lagging.—Lagging of sheet iron or steel is more durable than timber for out-of-door service. The preliminary work of bending wooden rings, and filling up with a non-conducting material is the same. But the sheet metal is not screwed to the rings, but retained with bonds. Often a layer of wood lagging is interposed between the felt and the sheet metal. This is not then fitted with tongues and beaded, but consists of roughly sawn strips laid round between the felt and the sheet metal.

Lagging up.—The method of building up cylindrical pattern work by lagging, being long narrow strips attached to cross-bars. The method economises timber, but of more importance is the prevention of, or minimising of shrinkage and warping.

The number of *lags* is governed by the diameter of the piece of work. Strips usually range between about 2 in. wide, by 1 in. thick in the smaller, to 4½ in. wide by 3 in. thick in the larger kinds of work. There may be from half a dozen to twenty lags or more in the circle. The cross-bars on which they rest range from about 8 in. to 15 in. or 16 in. apart. The object in any case is to economise material as far as is consistent with the construction of a strong and rigid pattern.

The lags should be sawn out a few days previous to use, to permit them to take any change of shape, and shrink a little before being worked up. The bevel of the edges can be sawn at once on the canting table of a band saw. The cross-pieces, jointed and dowelled, have their facets planed to receive the strips; and one-half of each is laid joint face downwards at the proper spacing on a true bench, or a joint board, and secured temporarily with nails or screws. The best way to build up is to begin at the two edges next the joint face, Fig. 54, A, thence gradually working up to the last space at the top, as in B. The edges are first planed and checked by a bevel set to the angle. But the joints are corrected by chalking before gluing them. They are rubbed over each other to work out superfluous glue, are held with dogs until dry, and usually secured to the cross-bars with wood screws having their heads sunk in centre-bit holes. Though the facetted edges of the bars are also saturated with glue, this alone would not afford sufficient hold without screws. Good, well made glued joints are essential along the edges, otherwise the pattern will not endure prolonged usage.

When one half-pattern has been built up in this way, it is detached from the board and turned over joint face upwards, C, and the other halves of the cross-bars dowelled on, and the lags fitted and glued on them. The holes into which the screw heads have been sunk are now filled with wood plugs, centre plates screwed on the ends, and the turning done.

Lagged column bodies generally have some extra fittings which are not lagged, as bases and

capitals, with mouldings. These are not included in the lagging, unless they are of small dimensions, because of the waste of timber that would result from the turning down of the body or shaft from the larger base or capital. These are made by gluing extra blocking on the flats of the lagging before the latter is turned, as at D. There are many ways of fitting such, depending on their shape and dimensions. Flanges and prints are differently fitted. Flanges are frequently let into a recess turned in the column body, E, F, but if they form portions of capitals or bases they may or may not be let in. Prints are frequently formed in an end block of extra length, E, or turned on the lagging, extended to include them, F. But if there is much difference in their diameters and that of the bodies, they are generally made separately, plank way of the grain, G, and screwed or bolted on the ends of the lagged portion. Large mouldings are made either from the solid, or else are built up in segments, both being shown at G.

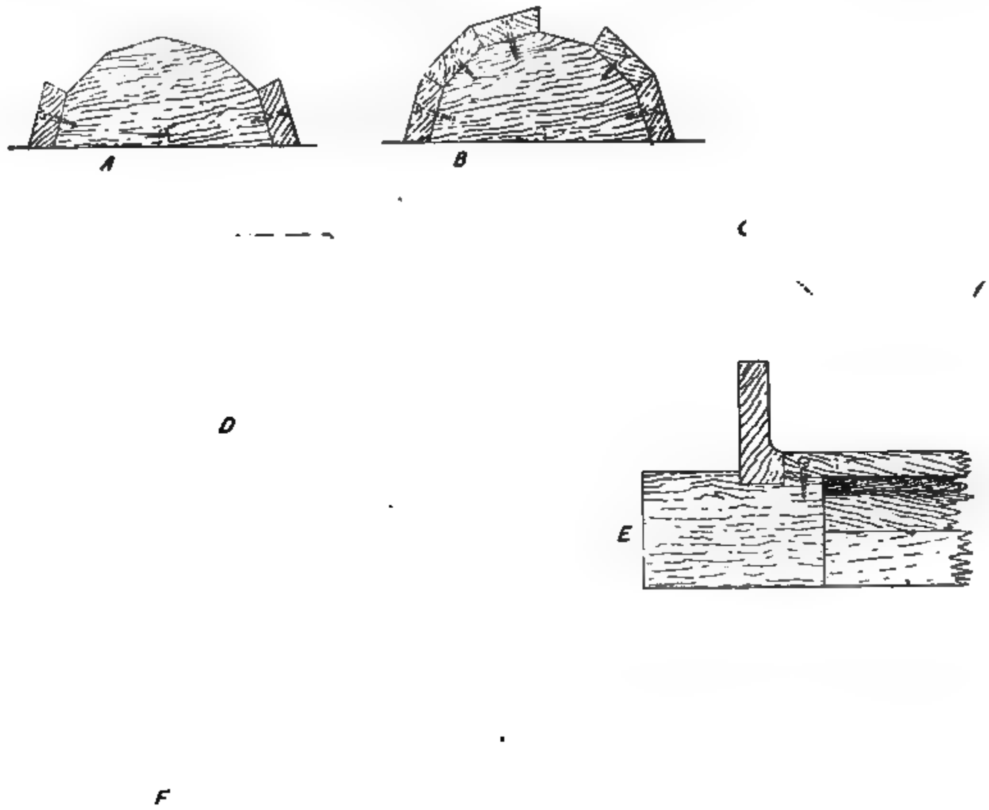


Fig. 54.—Lagging up.

Laminated Core Plates.—The cores of magnets, and particularly those subjected to reversals of the magnetising current, such as the armatures of direct and alternating current dynamos and motors, and all electro-magnets excited by alternating currents, are heated by hysteretic and eddy current effects. *See* **Dynamo, Hysteresis, Foucault Currents,** &c.

To reduce this effect, the cores instead of being a solid mass of iron, are built up of thin laminations, which are often (and particularly in dynamo and motor armatures) insulated from each other by coatings of insulating varnish. *See* **Dynamo.**

Lamp Columns.—Cast-iron columns made

in plain and ornamental designs. They are seldom made in classical proportions. When slender, and varying but slightly in dimensions, they are cast in one piece. But when the lower portion is much larger than the upper, a joint is usually made with a projecting pin on the upper shaft fitting a recess in the lower, and secured by stemming lead in the joint. Plain mouldings on base and capital are readily cast, but highly foliated capitals are generally made separately. A moderate amount of foliation is readily moulded on the main column by suitable division into loose pieces, but Corinthian capitals give much trouble. These are, therefore, often cast separately; or, frequently the foliations are made as separate pieces, and screwed on.

The coring of columns should follow in the main the external outlines to keep the thickness of metal nearly uniform. This, however, is not carried to an extreme, since it would be almost impracticable to follow every curve in the outline, but an average is struck. Large flanges and joggles are cast on lamp columns to afford a firm support. Lamp columns are cast horizontally, in moderately grey iron which will run well.

Lancashire Boiler.—A two-flued horizontal boiler derived from the Cornish, which it resembles in all essentials excepting the substitution of two furnace flues for one. It was introduced by Fairbairn, and Hetherington of Manchester in 1844; hence for some time termed the "Fairbairn boiler." The details of the Cornish boiler shown in Vol. IV., page 80, apply in the main to the Lancashire. The views of the battery of boilers adjacent, Fig. 55, with the details succeeding, illustrate the design with ample clearness. The circular seams are double riveted, longitudinal seams are double riveted,

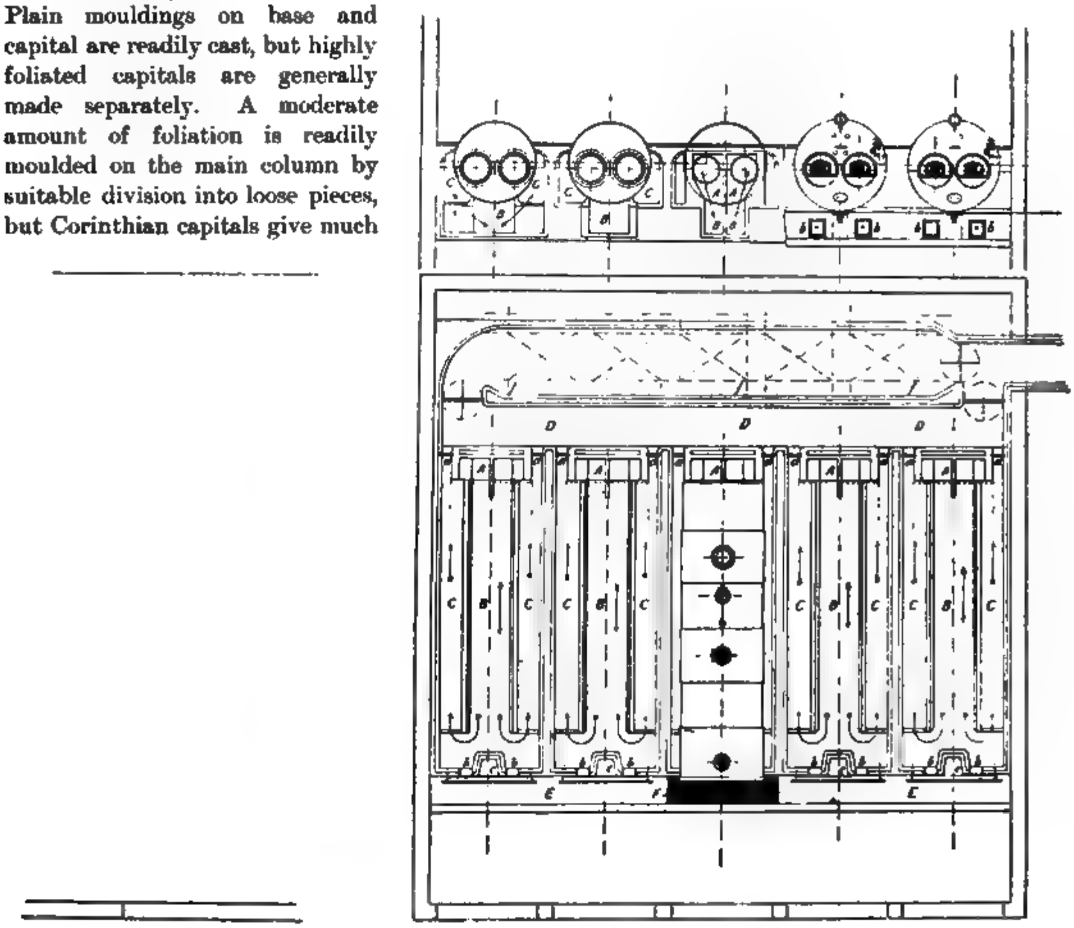


Fig. 55.—Battery of 30 ft. by 8 ft. Lancashire Boilers, with Economiser. (Daniel Adamson & Co.

with double butt straps. The latter do not come over the brick-work flues, or on the seatings, or under the mountings. *Square plating*, or parallel belts of plates, are used. The butt straps are thinned where they go beneath belts, and corners are thinned where they overlap. The thinning is done by planing (see the upper illustration in Fig. 56), or by hammering (as in the lower illustration in Fig. 56). The last named allows of the insertion of an extra rivet, Fig. 57, the metal being spread sufficiently by hammering to permit of this.

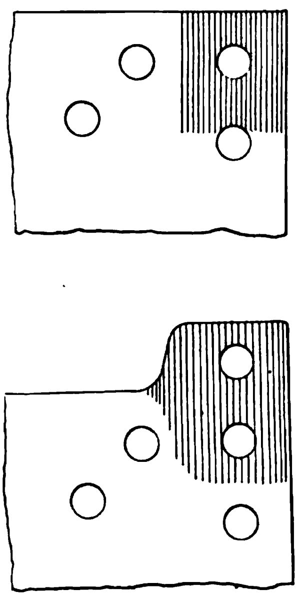


Fig. 56.—Thinned Corners.

The diameter of the shell of a Lancashire boiler is settled by that of the furnaces, the internal diameters of which range from 2 ft. 9 in. to 3 ft. in diameter. Sufficient space must be allowed between furnaces and shell for cleaning and repairs; 5 inches is the minimum between the flues, and 4 inches between the flues and the shell. Flues of 2 ft. 9 in. diameter require a shell of 7 ft.; and flues of 3 ft., one of 7 ft. 6 in. The diameter of the shell is taken as that within the smaller belts of plating. There is generally a 9-in. water space above the flues, and 2 feet of steam space.

The designs of the end plates have been settled by experience. Being flat, they are necessarily stayed, but the staying is done in such a way as to permit of a slight amount of elasticity. If this were either insufficient, or excessive in amount, the evils of grooving and furrowing would result around the furnace flues in consequence of the *breathing* movements due to expansion and contraction of the flues. The stays are arranged to allow of some little movement between the flues and the terminations of the stays, not as in the older practice, in which the stays were brought right down to the flues. And instead of using seven stays, as was formerly done, five is the number in a standard Lancashire boiler. As the stresses are practically taken entirely by the stays, and the furnace flues, the end plates are thin.

Fig. 58 shows the usual arrangement of stays in the front end plate. The spacing of the centres of the flues apart, and below the centre line of the shell, varies in boilers of different sizes, in order to maintain sufficient water spaces. Two of the gusset stays are not radial like the others, the object being to give more equal spacing than radial stays would afford. Their centres point to the centre *a*, or tangentially to the circle *b* touching the flues. The distances *c*, *c*, usually 9 in., are the breathing spaces, and the rivets for the gussets are on arcs corresponding therewith, as are those of the furnace flues. *d*, *d* are also breathing areas. The diagram, Fig. 59, is drawn to illustrate the areas supported by each stay above the furnaces. There are differences in the staying of the front and back plates.

Lancashire boilers, like Cornish and Galloway types, have to be set over smoke flues of brickwork, which are of two types:—the Wheel Draught, less used, and the Split Draught, which is common.

Construction.—In the construction of a Lancashire or Cornish boiler the following main operations are involved:—(1) Marking

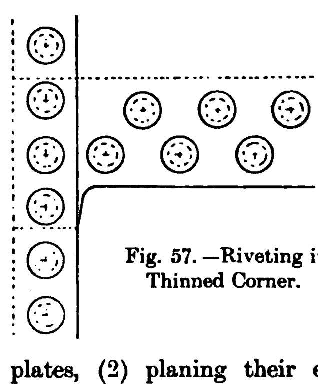


Fig. 57.—Riveting in Thinned Corner.

out the plates, (2) planing their edges, (3) rolling the barrel plates into the cylindrical form, (4) flanging the end shell plates, (5) welding and flanging the furnace tubes, (6) preparing and inserting the cross tubes, (7) tacking tubes in line, and drilling and

reamering the rivet holes, (8) riveting up, (9) preparing the gusset stays, and riveting them in place, (10) riveting the seatings for the various valves, &c.

(1) *Marking out the Plates.*—Plates are delivered from the steel works with their edges roughly shorn. Modern specifications demand that the edges of boiler plates shall be planed, both to remove incipient cracks, and to facilitate caulking. Plates are therefore marked by rule and trammel, or in all standardised work from another templet plate. Rivet holes may or may not be marked at the same time, depending on the facilities for drilling existing in the shop. Punching for boiler plate is practically ousted from shops of repute.

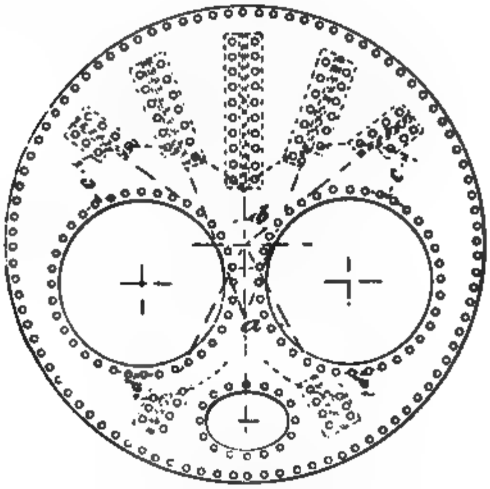


Fig. 58.—Stays in Front Plate of Lancashire Boiler.

Fig. 59.—Diagram of Areas supported by Stays.

(2) *Planing the Edges of the Plates.*—The edges of plates, including those of the butt straps used for longitudinal riveted seams, are planed in a special type of machine—the plate edge planer. The plates are bolted to a bed, and the tool and its box traverses, cutting on both forward and return strokes. Many machines have provision for planing two adjacent edges of a plate at the same time.

(3) *Rolling the Barrel Plates into the Cylindrical Form.*—This is done in a machine containing three rolls; one, or two of which have their centres adjustable in relation to the other two; or one in which adjustment provides the means whereby cylinders of different diameters can be rolled. Unless the diameter is very small, the plates are not heated, but rolled while cold. The circle of the barrel is completed by rolling, the edges meeting but not overlapping. They are united by butt, or covering straps, double or treble riveted, so preserving the circle absolutely for purposes of strength. The barrel rings are parallel, and fit within and without adjacent rings—square plating. In telescopic plating, now obsolete, the rings were frustra of cones, and the smaller diameters all faced in one direction.

(4) *Flanging the Rear End Shell Plate.*—These were formerly united to the shell, like the front plates, with a ring of angle iron. They are now flanged, as being less liable to develop grooving. If the flanging is done by hand work it is accomplished in short successive heats of 12 in. or 14 in. at a time. But most work of this kind is done in an hydraulic flanging press, having dies that bend over the entire flange in about a minute. The edges of this flange, as also that of the front end plate, and of the angle ring which unites it to the shell, are turned in a special machine, having a chuck with a horizontal table to carry the work.

(5) *Welding and Flanging the Furnace Tubes.*—Rivets exposed to flame are not permitted in good practice, hence the furnace tubes or flues are welded. The plates are rolled similarly to shells, and then welded by

an overlapping seam, or by the insertion of a bar (glut weld). This is done by hand, or under a special flue welding hammer. Afterwards the flanges are bent in a machine, the tube being rotated between revolving rollers. The rings then go to a special lathe to have the flanges turned. The holes are either drilled now singly, or adjacent tubes have their flanges drilled through. If conical tubes are inserted that is done now, but if not the tube lengths are all riveted together ready for insertion in the boiler shell.

(6) *Preparing and Inserting the Cross Tubes.*—If conical tubes are inserted, as is generally done, these are properly made and fitted before the flue lengths are riveted. They are first bent round a mandrel or in bending rolls, and welded with a lap joint, or a glut is inserted. The ends are then flanged, the tubes inserted in the holes cut for them in the flues, and riveted and caulked.

(7 and 8) *Making Rivet Holes, and Riveting up.*—This is a matter of much importance, as the safety of the boiler is jeopardised by the neglect of certain precautions which experience and common-sense have justified. No punching of rivet holes is now allowed, but they are drilled, and around this apparently trifling detail a number of special drilling machines have been designed, machines whioh not only drill, but pitch the centres of the holes correctly at the same time. After the holes are drilled, the sharp edges or arrises are removed by countersinking, to prevent scoring of the rivets. There are distinct machines for drilling the seams of shells, and the flanges of flues, and variations again in design to suit different classes of boilers. The rivets are not often now closed by hand hammering, but by machines, either fixed or portable, and usually actuated by hydrostatic pressure.

(9) *Preparing the Gusset Stays, and Riveting them in Place in the Shell.*—This is done before the front end plate is riveted up to the opposite ends of the gussets. The work of riveting is commenced at one end, either front or back, the furnace flue complete being riveted first to one end plate. The work on the shell is then proceeded with in sequence, circular and longitudinal seams being riveted, each section being held temporarily with tacking bolts. To the end plate, last inserted, the yet free end of the furnace flue is riveted, and the ring of holes for the circular seam for that plate is drilled and riveted up.

(10) *Riveting the Seatings for the various Valves, &c.*—These seatings, or stand pipes, or blocks, or mouthpieces, are short flanged tubes, which are riveted to the boiler shell to receive the safety-valve, stop-valve, blow-off cock, &c. Formerly made in cast iron, then in cast steel, they are now almost invariably of mild steel plate, rolled, welded, and flanged by machine. The fitting and riveting of these to the boiler shell completes the boiler ready for testing, and the fitting of the furnace doors, grates, and bridge, which is not the work of the boilermaker.

Flues and Setting.—Returning to Fig. 55, which illustrates the flues for a battery of five Lancashire boilers, with sundry face views and sections; the following remarks relate to these details.

Lancashire boilers are set over brick-work flues to prolong the period of contact of the gaseous products of combustion with the shell. This has the effect of reducing the temperature of the gases to about 600°, or nearly the melting point of lead. At the same time, heat is rendered up to the boiler. But though it is usual to reckon the area thus exposed as heating surface, it is of but slight value for that purpose. At the Wigan coal trials of 1868, the external flues of a Lancashire boiler were removed, and the gases passed directly from the internal flues to the chimney, with very little difference in the amount of water evaporated per lb. of coal.

The flues are designed to give the maximum of cross-sectional area, and the minimum of bearing surfaces for the boilers to rest on. Large flues are necessary to carry off the volumes of gas generated in the combustion chamber. Also to permit of proper inspection of the shell plates, to permit of which the inspector must get along them. The stoker must also creep through them to remove accumulations of soot. Large flues also leave narrow bearing surfaces on the brick-work seatings. The width of these seating blocks should not exceed 4½ in. where they come in contact with

the boiler. They are of non-porous fire-clay bricks which do not retain moisture. Broad surfaces and common bricks would retain moisture in contact with the plates, and produce external corrosion, which being concealed would be an element of risk. This has been the cause of many boiler explosions. Common bricks are used for the main construction, the flues are lined with fire-bricks, and the walls and flues are carried on a deep bed of concrete from 8 in. to 10 in. thick. The setting shown is termed a *split draught.* The products of combustion, passing out from the furnace flues at the hinder end of the boiler, go down the downtake A into the middle or bottom flue B, right away to the front end. Thence they divide, and passing to right and left enter the side flues C C to the back of the boiler, into a main flue D, and thence direct to the chimney, or through an economiser, as in the illustration. The reason why the gases are brought along the bottom of the boiler and returned along the sides, instead of in the opposite sequence, is this:—The coldest water in a boiler is at the bottom. This therefore receives the gases hot from the furnace flues. If the gases were brought along the side flues first, and returned along the bottom, they would have rendered up most of their heat before reaching the bottom hinder end, where the coldest water is.

The draught is regulated by dampers *a a* at the rear of the smoke flues. The soot doors are situated at *b b*. The ash-pit E extends along the front of the boilers, and is covered with lengths of chequer plate F, removed when the ashes have to be cleared. The recesses *c c* receive the blow-off bend.

Lancewood.—A tree of the natural order *Anonaceæ*, the supplies of which come from the West Indian Islands. It resembles boxwood in its yellowish appearance and characteristics. Its fineness of grain renders it suitable for general turnery, and rods, and shafts requiring flexibility. It is tough, strong, and elastic. A cubic foot weighs from 52 to 63 lb.

Lantern Gear, or **Pin Gear.**—A pin or lantern gear has true cycloidal teeth, though the trundles or pins are cylindrical. It is well understood that by the selection of generating circles of suitable diameters, almost any variation in the curvature of these teeth can be attained. A small circle will produce a spreading flank, a large circle narrow flanks. A circle of half the pitch diameter will produce a radial flank, with corresponding differences in the faces of the wheels with which these flanks engage. When the generating circle becomes larger than the radius of the wheel, the flanks of which it describes, those flanks become curved inwards towards each other. If now the diameter of the generating circle is increased still more, the curvature of the flanks will be correspondingly narrowed. If it is made of the same diameter as the wheel it will not roll therein, but its point of contact will remain a *point*; or, carrying out the analogy, its cycloid might be regarded a point only. Now this

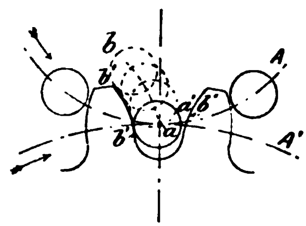
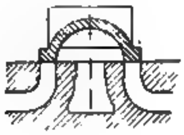


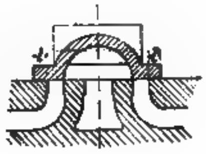
Fig. 60.—Lantern Gear.

point is the basis of the lantern gear. In Fig. 60, *a* is the hypocycloidal point generated by a circle of diameter A rolling within the pitch circle A; *b* represents the flank of an epicycloidal curve, generated by the same circle A rolling without A′. If the point *a* could become a rigid mechanical substance, it would gear with *b* correctly. But for *a* is now substituted the circle *a′* concentric with it, and arcs of the same radius as *a′* are struck from the curve *b* as from a centre line, and the curves *b′ b′* drawn in contact with these arcs are the curves of the wheel teeth, which will truly engage with the pins or trundles *a′*. This therefore is an example of a gear wheel having faces only, since the space below pitch line does not come into contact at all, being merely cut away to clear the trundle.

Lap and Lead.—These terms relate to certain features of the slide-valve. Invariably now the length of the valve is greater than the width across the outside ports. The amount by which the ends of the valve when at mid-

stroke extend beyond the outer edges of the ports is the lap, or *outside lap*. The object of this is to regulate the expansive action of the steam, for otherwise, if the steam were admitted from the moment of commencement to the moment of the termination of the stroke of the piston, as with the old valves, Fig. 61, the efficiency of the engine would be greatly reduced. The admission of steam until the completion of the stroke produced strain and shocks, besides loss due to the non-utilisation of its expansive energy; and as the steam could not escape from one end before admission at the other end, there was considerable loss due to back pressure. Added to these evils were imperfections in the operations of the valve gears, which prevented prompt opening and closing of the valves. Hence the effect of lap, Fig. 62, is to cut off the supply of steam at some fractional part of the stroke, which permits that enclosed in the cylinder to work expansively, being shut in so long as the valve continues to move over a distance equal in length to its lap.





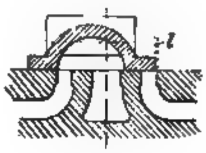


Fig. 61.—Valve without Lap. Fig. 62.—Valve with Lap. Fig. 63.—Valve open to Lead.

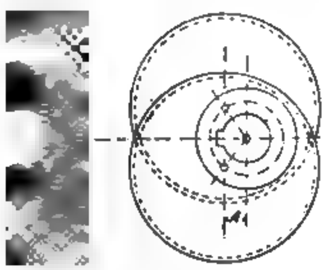


Fig. 64.—Diagram of Linear Advance.

Hence the longer the lap allowed, the shorter will be the period of the admission of steam, and the greater the degree of expansion. The amount of lap is the distance, *l*, Fig. 62, by which the edges of the valve overlap the ports when in middle travel. With a fixed eccentric, and rod working directly to the valve spindle, this expansive working is invariable in amount; but using a link motion, a range of expansive working can be secured. Back cut-off valves are also employed for the same purpose. *Inside lap* is that allowed on the exhaust side, hence termed also *exhaust lap*. Its effect is to delay the release of the steam.

Lead is a small width of opening of the steam ports allowed at the beginning of the stroke of the piston, Fig. 63, *l*. Its object is to fill the passage with steam before the piston comes quite to rest, and so act as a buffer—*cushioning*—to avoid shock and strain. It is always small, seldom exceeding $\frac{1}{8}$ inch in fast running engines, and as little as $\frac{1}{32}$ inch in slow ones. *Inside lead* is the reverse of *inside lap*, being clearance to exhaust, or *exhaust lead*, as inside lap is a check to exhaust.

In the old valve without lap, Fig. 61, the eccentric sheave was set to an angle of 90° with the crank pin. But when lap is given, the sheave must be set in advance by the amount of a single lap, or if lead is given, by the amount of lap + lead = A in Fig. 64. This is *linear advance*, measured parallel with the line of 90°. Angular advance is that measured in degrees between the vertical passing through the crank shaft, and the diagonal through the centre of the sheave.

Latent Heat.—If the bulb of a thermometer be surrounded by crushed ice contained in a vessel, and heat be applied, a remarkable phenomenon will be observed; though heat is continually passing into the vessel and the ice gradually melts, the thermometer refuses to rise above 0° C. until all the ice is melted. As with ice, so with other solids; the temperature remains constant from the time fusion commences until it is completed. The heat thus used up in changing the state of matter is called latent heat (L. *Lateo* – I lie hid), and the amount of heat so rendered latent varies with different substances. It may be measured,

the unit of heat being the amount of heat required to raise the temperature of a unit weight of water 1° C. Now, if a kilogram of water at 79° C. be mixed with a kilogram of ice at 0° C., the temperature of the two kilograms when the ice is melted is only 0° C., *i.e.*, the 79° of the water have been used up in converting the ice into water. Hence the latent heat of water or the latent heat of fusion of water is said to be 79 thermal units. The latent heat of iron is 23, and of lead 5·3.

Conversely, heat disappears when liquids are changed into gases. The mercury rises in the thermometer placed in water which is receiving heat; but as soon as boiling point is reached and the mercury stands at 100° C., the thermometer becomes stationary although heat is continually passing into the liquid. The latent heat of evaporation of water or other liquid is the number of units of heat necessary to transform a unit mass of water at boiling point into vapour at the same temperature, and by blowing steam (100°) into a kilogram of water at 0° until the water boils, it is found that the latent heat of steam is 536 thermal units.

This apparently peculiar behaviour of matter when changing from one state to another is explained by the modern theory of heat. If we regard heat as energy, as molecular motion, the failure of the thermometer to indicate any increase in sensible heat is due to the fact that molecular activity is greatly increased, and when circumstances lessen molecular motion, that is, when a liquid solidifies, we might expect heat to be evolved, which is found to be the case.

Lathe.—The essential principle of the lathe is that of two point centres on which the work rotates, and a rest to support a tool operating upon the surface of the work. This skeleton outline is somewhat disguised in many types of lathes, but it is there nevertheless. If the work revolves between fixed centres, the lathe is termed a dead-centre one, but there are few turning lathes in which the principle is retained. Most of them have a running mandrel by which the piece is driven, thus introducing a live centre. Hence the term *live head*, applied to the headstock or fast head, or fixed head; the other centre is on the loose headstock, or poppet. Both of these heads stand upon a bed, and the loose headstock is adjustable to and from the fast headstock to accommodate varying lengths of work. In some types of lathes the poppet is discarded and the work supported from the headstock alone, to permit of boring. The other element in a lathe is the rest, either of hand form, being then simply a bar upon which the turner rests the tool at the proper height, and manipulates it, or a slide-rest which grips the tool and moves it in unvarying planes, by means of slides operated by screws.

Lathes are driven by treadle, or from belting driven from a countershaft overhead, or by an electric motor. The motion is transmitted to the spindle or mandrel by belt cones, with or without the intervention of back gears, or in a positive manner by chains or toothed gears. The work is driven from the mandrel by faceplates or chucks screwed on the nose, or by internal chucks. If support is afforded by the poppet, the headstock fixing is simple, but if the spindle has to carry the work by itself, then a positive grip must be obtained.

The rest is adjustable along the bed in the plainest lathes to suit the working of the tool at different locations. In sliding lathes the rest is mounted on a saddle or carriage to slide it longitudinally, and so travel the length of a piece of work. The sliding may be done by a rack and pinion operated by handle, or in a self-acting manner through a shaft driven from the headstock spindle. The addition of a self-acting cross feed to the transverse slide introduces the surfacing type. In the most complete lathes screw-cutting motion is incorporated, the saddle being travelled along the bed at a certain definite rate by a lead screw driven through change wheels from the spindle, the ratios of these being variable.

The methods by which lathes are varied to suit special classes of work include the duplicating of rests, to bring additional tools into operation, and the use of turret rests, which produce the same effect in a different manner. In one case several tools are brought to work simultaneously at different portions of a job, in the other a number of tools are brought into operation in succession. The inclusion of cross-slides also increases production by enabling forming,

cutting-off, &c., to be done either during or after turret tool operations.

The work done in lathes, with or without the help of auxiliary attachments, includes turning, boring, facing, drilling, screwing, forming, knurling, grinding, milling, and cutting-off.

Lathe Beds.—These tell an obvious story of evolutionary processes, from the first wooden beds or shears to the latest massive broad-faced beds, used in the high-speed lathes.

The earliest beds were of wood, Fig. 65, A, comprising two shears, separated, and united through cross-bars. These in course of time were faced with flat plates of iron, and also in American practice with plates having raised ribs with convex edges, *a*, *a*, as guides to the poppets. From these designs branched off the English type of iron bed with flat ways, and the American with vee'd guiding edges. At first the iron beds were cast with separate shears, B, following the timber design, in which the cheeks were bolted together at the ends only, leaving a central space along the entire length for the clamping bolts of the poppet and rest. In the American design the space was also necessary for the hanging weight which maintained contact of the carriage with the vees. Many of the early English beds had one flat, and one vee, B, some had both ways vee'd. From these diverged the English bed with flats of increased width, C, and outer vee'd edges, D, for guidance, and cross ribs, C and D; and the American with vees duplicated, E,

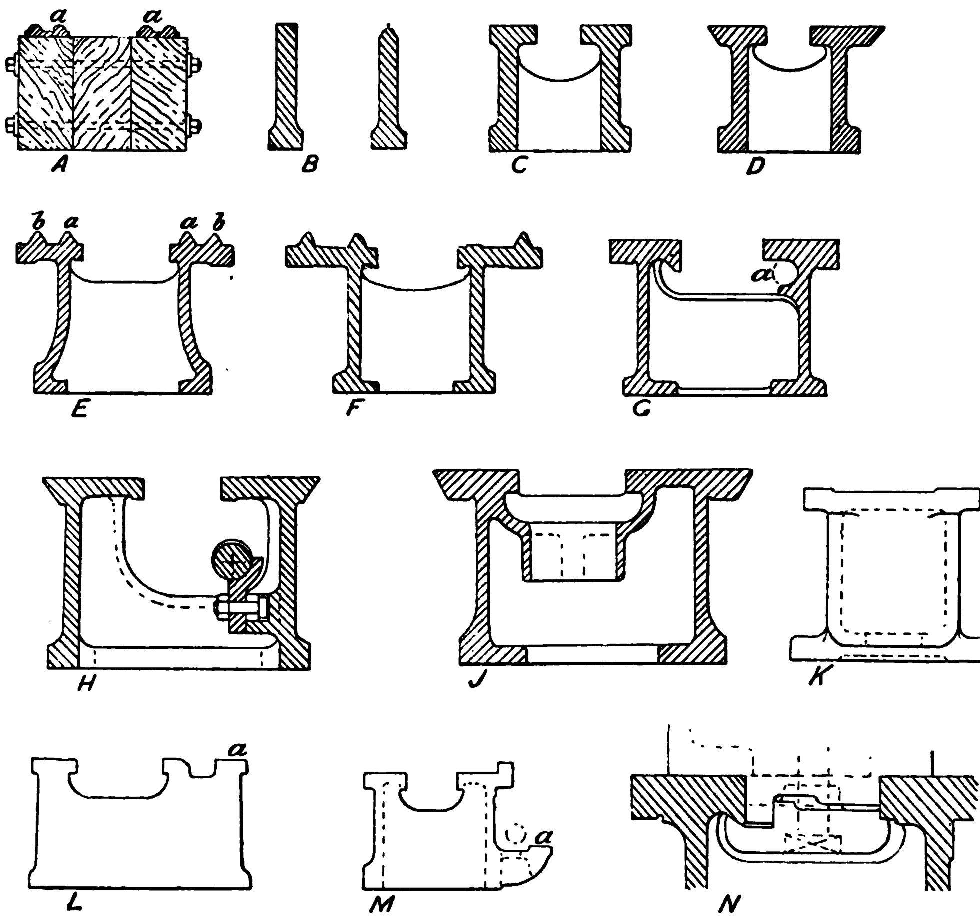


Fig. 65.—Lathe Beds.

one set, *a*, *a*, for poppets, and one, *b*, *b*, for the rest, and with or without cross-girts. When the latter were absent the vertical webs were generally curved outwards as at E, to afford some compensating rigidity. In F the poppets rest on a flat and a vee. The sectional forms of beds are modified by the position of the lead screw. In G and H, where the screw is placed within the shears, the section is widened with advantage. In G, the Sellers design, the screw revolves in a recess underneath the front shear; in H, the Whitworth, it is carried lower down, and rests on bearings.

In present-day practice the importance of designing the bed to afford rigidity under heavy cutting is recognised and carried out in different ways. A bed having a nearly solid or enclosed form is shown at J. The longitudinal plating is broken only at intervals by circular wells through which the chips and oil fall, and the cross-girts are of ribbed section. The hollow boxed form would be the strongest, but it is not always practicable, except in turret lathe beds, K, which have their turret bases, and cut-off slides clamped in a fixed position, the necessity for having bolts passing between the shears being thus obviated.

Tee-grooves are used in the largest sizes for the clamping bolts. Cross-girts are also of box section. Beds are made wider and deeper than formerly to resist the torsional stress of heavy cutting.

An important modification which has already been applied extensively to lathes is the Lang narrow guiding strip *a* on the front edge of the bed L. The front part of the saddle is made to embrace this strip on both sides, and a long gib strip takes up wear. The saddle is not guided, therefore, by the total span of the bed, as usual. The resulting advantages consist in diminished risk of cross-working, due to the great proportion of length compared to width of bearing on the strip. The guiding surfaces are also brought very close to the rack and lead screw. Another recent design, applied to high-speed lathes, is the Darling & Sellers "double-tier" bed, M, which has a supplementary ledge, *a*, situated on the front of the bed, taking the weight of the overhanging saddle and increasing the effective bearing width or span. This bed has also a narrow guiding strip of the Lang type. N shows a method of forming the underlip of the shear, an *inverted vee*, which is commonly adopted, to pull the poppet over to one side by the vee edge and clamping plate. The bed at O is so made. The advantage is that the poppet is always pulled over to one particular side of the shears, and so its accuracy of alignment remains, irrespective of slackness which may develop in time between the poppet base and the shears.

It is generally considered sufficient to bolt a true bed on a truly levelled foundation of stone or concrete, or in the case of small lathes, on substantial floors. In some American practice a three point support is adopted. In this, one standard is bolted down in two places, and the other pivots on a pin that passes through a lug in foot and bed.

Fig. 66.—Adjustable Jaw.

The standards of lathe beds are made as ribbed frames, or in cabinet designs. The latter are rapidly superseding the former. They are not only more rigid and stable, but afford convenient receptacles for tools and change wheels. Strips are cast within to carry wooden shelves, and a door is generally fitted.

Lathe Chucks.—A selection of the principal kinds of chucks used on lathes is given in this article, while some others occur under various headings, and in connection with certain lathes. The **Face Plate** may be termed a chuck when it is fitted with adjustable clamping jaws, Fig. 66, four of which are usually bolted in position, and tightened on the work by the screw. The jaw may be reversed end for end. A face plate with permanent jaws, termed a dog chuck or common jaw chuck, is shown in Fig. 67, from an example by Charles Taylor, giving views of the front, with two jaws in place, also with one screw only in place, and one of the back of the plate; while the section

above is taken through the plate and dog, with its screw. Each dog is moved radially in its groove by the square-threaded screw, which is held in place endwise by a collar fixed by two pins driven partly in the plate, and partly in the collar. The jaws slide in shallow recesses on the face of the plate, which take the side thrust. On the screwed tail of each jaw there is a nut and washer, tightened up when the job is accurately chucked. The central boss of the plate is threaded to screw over the lathe spindle nose.

By incorporating the style of jaw in Fig. 66 with a plate, the chuck in Fig. 68 results, with the advantage over Fig. 67 that the jaws may be run off their screws and reversed, for holding bars. A series of circles is struck on the face of both these chucks, for approximately setting the work by. In Fig. 68 tee-slots are cut in the plate to carry bolts as an addition for holding certain awkward jobs.

Self-centring chucks differ from those just illustrated in possessing a simultaneous motion of all the jaws, enabling a piece of work to be gripped concentrically. The concentric or universal chuck, Fig. 69, has three jaws, two of which only, A, A, are visible in the section, sliding in tongued grooves in a plate B, within which rotates a plate C, provided with a scroll upon its face, engaging with grooves on the backs of the jaws. On turning C by a hand grip on its knurled periphery the jaws open or close in unison, an extra grip being given if required by inserting a tommy bar in one of the radial holes in C. The back plate D keeps C up to position, and serves as a means of attachment of the chuck to the spindle, through an intermediate face plate E, held to D with three set-screws. The chuck, Fig. 68, is held to a similar plate by bolts fitting in the countersunk holes surrounding the central hole.

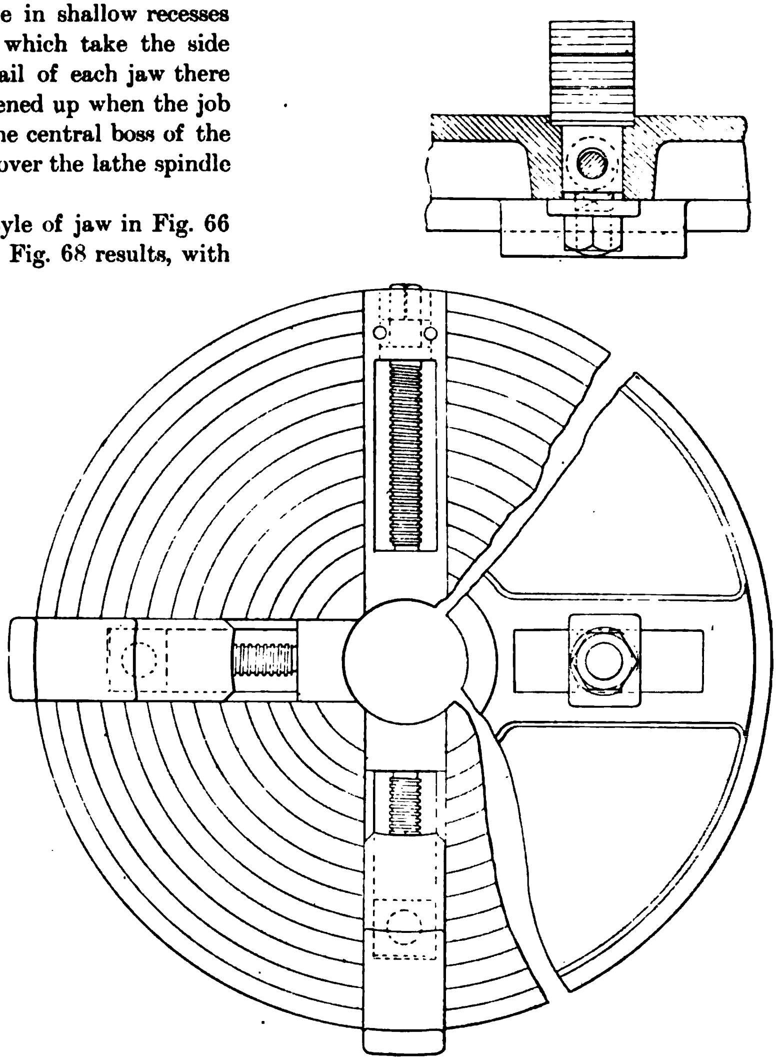


Fig. 67.—Dog Chuck.

The styles of jaws fitted to chucks of the type Fig. 69, may be any of the varieties in Fig. 70; those at A grip on the outside of work by any of the steps, or on inside work by the longest part of the jaws; they are reversed at B to grip inside work by the steps, or around bars by the long inside portion. The jaws at C hold bars or drills only, and the bodies are sloped off to

be out of the way of the operator as much as possible. D are blank jaws, which are cut into various shapes to suit special jobs.

If concentric and independent movements are combined in one chuck, it is termed a combination chuck. Such a type is shown in Fig. 71. Each of the three jaws is movable by a screw (held from endlong motion by shoulders about the centre) turned with a square-ended spanner inserted in the hole in the end. The screws rest in secondary jaws which are moved all together by the scroll at the back, revolved by either one of three pinions, turned with a key inserted through the holes in the body. In another style of combination chuck each jaw is moved by a screw, in the same manner as in Fig. 71, and each screw has a bevel pinion cut on it near the squared end. A circular rack lies below the pinions, and may be brought up into or dropped out of mesh with them by means of cam projections on the back of the ring, operated by a small lever. If the ring is out of gear, the effect of turning one pinion will simply be to move the one jaw upon its screw; if the ring is in gear it communicates the motion of the pinion to the others, and so all the screws operate their jaws.

The question of reversibility of jaws is one that must be considered from the point of convenience to the operator. It will be seen on examining Figs. 67 and 69 that the jaws cannot be reversed, in the one case because the nut of the jaw completely encircles its screw, in the other because of the curve of the scroll teeth on the back of the jaws; they could not fit the spiral if reversed, and the only way then is to have another set of jaws for internal work and rods, with the threads curving in the opposite direction, provided the jaws can be readily reversed on the screws. When reversible jaws are supplied with the scroll chucks, it is on account of lessened cost, as compared with two separate sets of jaws, and the effect is obtained by fitting auxiliary pieces to the jaw bases. They are sometimes fastened on with screws, additional security being afforded by dowel pieces standing out from the jaws, and fitting into recesses surrounding the screw holes. The two screws may have to be taken out for reversal, but by providing a third hole in the jaw base, the jaw may be slewed around, leaving in one screw, and putting the other back in the new position when the jaw is end for end. Another method is to fit the upper

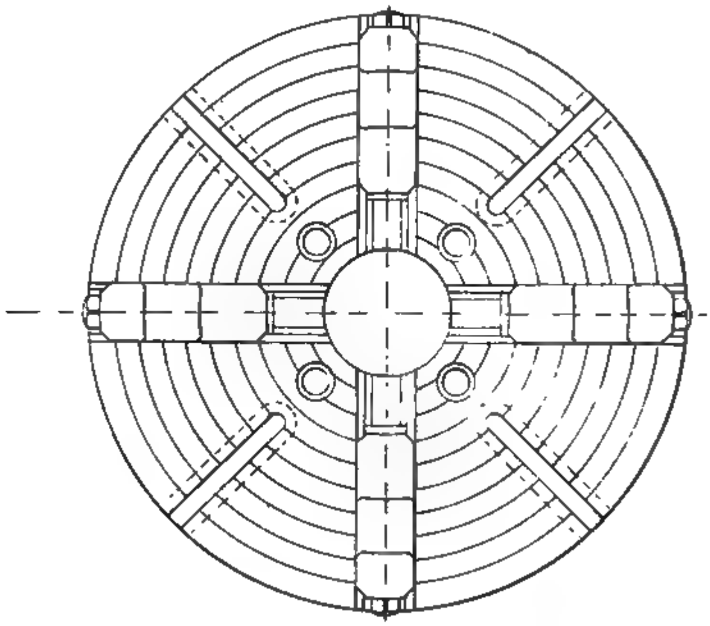


Fig. 68.—Reversible Jaw Chuck.

jaw with two or three dovetails, with or without additional hold by screws. There is one type of jaw which is made to reverse bodily, but the scroll teeth are not of the usual form, with their outside and inside edges both curving in the same direction. Instead, the outsides curve in an opposite direction, so that whichever way the jaw is put in, the threads will coincide with those of the scroll plate. A matter which may be mentioned in connection with the fit of scroll threads is that the threads on the jaws obviously cannot match those at all positions of the diameter, on small and large radii. Consequently the bearing surface does not extend all along the thread equal to the width of

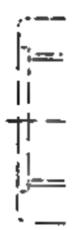


Fig. 69.—Concentric Scroll Chuck.

the jaw. An average has to be struck in making the teeth, a medium curve being imparted.

A departure from the ordinary scroll threads is made in the "spiral" chuck by Charles Taylor, which, instead of having square threads lying on a flat ring, has vee shaped threads on the inside of a cone-ring, A, Fig. 72, which shows an 8-in. two-jaw chuck. A is rotated by either of two pinions B, B, and slides the jaws C, C up or down the grooves in the body D, one pinion and portion of rack being omitted in the view. The advantages claimed for the spiral chuck are that the form of the threads is stronger than the square shape, and the cone rising up behind the jaws takes the thrust of work very solidly, instead of tending to allow the jaws to tip, as in the flat scroll.

In the larger chucks with three jaws the axis of the operating pinions is angular (*see* Fig. 73)—thus reducing the total depth and overhang of the chuck—and the spiral ring revolves on a

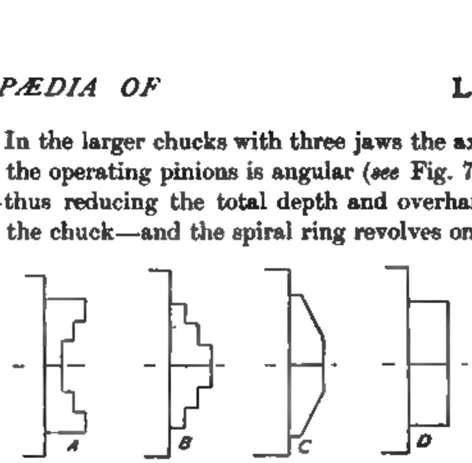


Fig. 70.—Chuck Jaws.

coned ring which may be adjusted with screws to maintain a good fit between the coned surfaces (*see* Fig. 74, showing a section through a plane of one of the jaws. This also illustrates the chuck face plate bolted on the back). A special form of key, Fig. 75, is used with the Taylor chucks. It has a small handle projecting from one end, to enable the pinion to be rotated rapidly, the final tightening being done as usual by grasping both ends of the handle. The gears and jaws, &c., are hardened.

There is a good deal of work for which the ordinary chuck jaws are unsuited, and this class is accommodated either by making special complete jaws of suitable shapes, or by attaching false jaws by screws to the main ones. In the first case the jaws are left soft, to be cut to shape by the user, in the second the jaws are hardened as usual, and the false portions are soft to enable them to be tooled. Brass-finishers are the chief users of these specially-cut jaws. The box body chuck, which has two jaws, and a rectangular body in which they slide, is a favourite pattern for brass work. The false

Fig. 71.—Combination Chuck.

Fig. 79.—Launching Cradle at Stern of First-Class British Cruiser "King Alfred," at Barrow. (Vickers, Sons, & Maxim, Ltd.)

Fig. 80.—Launching Cradle at Fore End of First-Class Battleship "Katori," for Japanese Navy, at Barrow. (Vickers, Sons, & Maxim, Ltd.)

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jaws are often fitted by dovetails instead of screws.

Valve chucks are a particular kind employed for gripping the bodies of valves, and other castings having two or more faces at right angles. The jaws are supported in brackets, and turn on bearings, an index and locking device being fitted to locate the rotating jaw in four or other positions, to successively present the different faces of the job to the tools. The opposite jaw merely turns in its bearing. In the best types ball races are included, to let the jaws revolve easily, without troubling to slacken the screws which press the jaw brackets together. Figs. 76 and 77, Plate III., show a valve chuck. The first view illustrates it without work in place, the second its appearance in the turret lathe, with a valve body gripped between specially shaped jaws bolted to the revolving jaws. The small handle seen to the right, in front of the upper bearing, serves to withdraw the locking bolt, and the knurled screw in front locks it after indexing has been done.

Brass-finishers' grab or clam chucks are of a very simple character, consisting of a couple of small jaws hinged and closed together with a nut to grip the work. Fig. 78 shows an improved type by C. Taylor. The

Fig. 73.

Fig. 74.

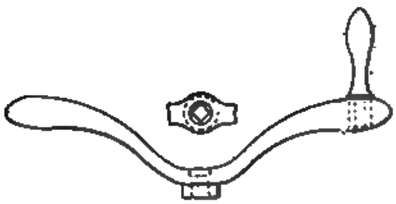

Fig. 72.

Fig. 75.

Fig. 72.—C. Taylor's Spiral Chuck.
Fig. 73.—Angular arrangement of Pinions.

Fig. 74.—Section through Jaw.
Fig. 75.—Handle.

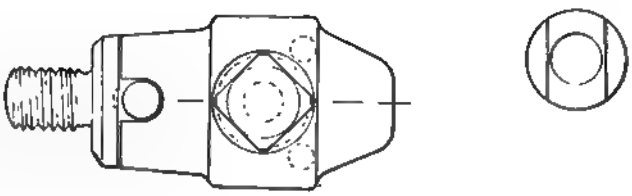

Fig. 78.—Grab Chuck.

spherical fitting of the bolt and its nut may be noted.

Launching.—The setting in motion of a mass of several thousand tons, and provisions for the stability of the vessel during the entire period of the launch, involves many difficult problems. Within a few years the launching weights of the biggest vessels have been doubled; that of the *Mauretania* was 16,250 tons, that of the *Oceanic* 10,750. Increasing the length also of vessels launched in narrow waterways, as in the Clyde and at Belfast, lessens the room available for the movements of a vessel before she must be pulled up. For this reason the *Great Eastern* was sent into the water sideways, a practice which is common also on some of the American lakes. But generally the launching slips are arranged for the vessel to enter stern first, the vessel's length being towards mid-stream, or at some angle with the water's edge.

In a launching slip, support is given to the vessel under the keel, and at both sides—on the *groundways*. The first is afforded by means of keel blocks, the second by cradles, fore and aft, which sweep up round the curves of the ship. The *building declivity* is the slope given to the ways; from $\frac{1}{2}$ in. to $\frac{5}{8}$ in. per foot, which on long vessels amounts to a total drop of several feet from stem to stern. The groundways, which are the *launching ways* on each side, have more slope, ranging from $\frac{3}{4}$ in. to $\frac{7}{8}$ in. Unless the ground has been well piled, or concreted, these are cambered lengthwise to the height of a few inches, the object of which is to prevent risk of the ship's weight bending them into a hollow form. The height of these ways must be sufficient, having regard to the height of the tide, to permit the ship to float clear without striking the ground.

The *launching weight* of the ship has to be estimated very carefully, and the position of her centre of gravity, and her displacement at successive positions. These, with related calculations, are gone into, and plotted, and also the pressures per square foot of bearing surface on the cradles, which range from 1 to 3 tons.

The groundway is built of teak planking, bolted down to transverse blocks of oak. It is 5 ft. or 6 ft. wide, to afford a sufficiently broad base to the *bilgeways*, which support the cradle. These are of fir, made up of balks, overlapping lengthwise, and bolted and dowelled together to form a total section of about 5 ft. wide, by 2 ft. thick. The lower faces are covered with teak planks, called the *sliding plank*. On the outer edge of each of the groundways a *ribband* of timber balk is bolted, and dowelled, giving clearance for movement between the cradles and the perpendicular sides, while preventing swerving of the cradles during the launch. The ends of the bilgeways terminate in abutment blocks, termed *cleats*, which prevent movement of the poppets of the cradles. On the outer side of each are fitted the *dog cleats*. The space between a dog cleat and its end of the ribband is occupied by the *dog shore*, a balk of about 10 ft. long, with steel shoes at the ends. One end is cut at such an angle that when it is knocked down it clears itself in falling.

The bilgeways support the *cradles*, which are of the same width; and comprise the *poppets*, standing nearly vertically in a *poppet board*, and connected longitudinally with steel *dagger plates*. The upper part of the cradle consists of *stopping up balks*, fitted to the curves of the ship's bottom. Between these and the upper surface of the bilgeways a space of about 4 inches is occupied with *slices* or wooden wedges for setting up the ship, or taking her weight off the cradles. Steel angles riveted to the ship's bottom keep the cradles in place laterally there, preventing them from slipping outwards, while they are tied together by *spread shores* under the keel, to prevent slip on the groundways. Hawsers are attached to the ends of the cradles to enable them to be removed by tugs after the launch. The front cradles are provided with cut-water edges. Shoring is provided within the hull to counteract the pressure of the cradles.

The ship is released by first setting up the slices to take the full strain of her weight on the cradles, after which some, or the whole of the keel blocks are removed by the knocking out of the wedges there. The last stage is the removal of the dog shores. These are knocked down by dropping a weight of several cwts. on them from a height of 16 or 18 ft. Until then, the shores are prevented from an accidental drop by *triggers*, or chocks of wood placed below them, which are knocked away at

Fig. 81.—First-Class Battleship "Katori," for Japanese Navy, on the Stocks at Barrow. (Vickers, Sons, & Maxim, Ltd.)

Fig. 82.—Launch of First-Class Battleship "Triumph." (Vickers, Sons, & Maxim, Ltd.)

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the last. If a shore fails to drop, which seldom happens, it has to be cut away with axes. In case a ship should fail to start, hydraulic jacks are kept in reserve to give her a send off.

If a waterway is ample, the speed acquired in launching is checked by anchors. But for narrow streams, heavy anchors are often stuck in the ground with lengths of cable to check the ship's progress. In the case of the *Mauretania*, friction plate slabs, loaded with weights, were used to attach the check ropes to. The vessel was brought to rest when her bows were only about 160 ft. from the end of the ways, notwithstanding that the ship had run about 800 ft. in fifty seconds. The launching weight of the vessel—16,250 tons—was carried on launching ways 6 ft. in width, and 35 ft. apart across their outer edges. The inclination was a trifle over ½ inch per foot.

An important detail is the lubrication of the sliding surfaces, which is done a week or two before the launch. To do this, the cradles are shored up, the ribbands temporarily removed, and the bilgeways hauled out sideways on sloping planks. A coating of Russian tallow, from ⅜ in. to ½ in. thick, is then applied to both groundways and bilgeways, often covered again with a mixture of tallow and beeswax applied hot. The sides of the ribbands are similarly covered. Variations in methods of launching are numerous, but the foregoing account states the leading methods and essentials without including many minute details. Figs. 79 and 80, Plate IV., and Figs. 81 and 82, Plate V., illustrate some of the foregoing descriptions.

Fig. 79, Plate IV., is a view of the stern of H.M.S. *King Alfred*, showing the launching cradle in position, just previous to launching at the Barrow-in-Furness yard of Messrs Vickers, Sons, & Maxim, Ltd. In this view is shown a wooden cradle in position supported with wood poppets resting on the sliding ways. This cradle is bolted together and lashed with that on the other side of the ship by chains. One of the dog shores is seen in the foreground in an inclined position, and also the triggers. Immediately over the dog shores are the wooden boxes in which are suspended the heavy weights; these latter are connected to the launching platform, as shown, by horizontal rope lines. When the ship is ready for launching the triggers are knocked out, the ropes are severed at the launch platform, and the released weights displace the dog shores.

Fig. 80, Plate IV., shows the fore end of the first-class battleship *Katori*, launched at Barrow, with the launching cradle in position. The check chains will be noted; these are connected to blocks of ground chains, termed *drags*, which are used for limiting the vessel's speed on reaching the water, thus enabling her to be pulled up within a reasonable distance.

A broadside view of the *Katori* is shown in Fig. 81, Plate V., as she appeared a few days before launching, with the supporting shores in position. These are removed previous to launching. The drag chains, already mentioned, are seen in place.

In Fig. 82, Plate V., a fine view of a launch is given, with the vessel in the water, just leaving the extreme end of the ways, with the drag chains trailing to the shore. This is the first-class battleship *Triumph*, built at Barrow for the Chilian Navy, and afterwards purchased by the British Government.

Laundry Machinery.—Laundry machines fall into three great groups, corresponding with the three operations—washing, drying, and ironing.

Washing Machines.—The machines used for washing are of cylindrical shape set horizontally, and comprising an inner cylinder or "cage" of perforated brass, rotating within an outer cylinder of steel. It is necessary to avoid the use of iron in contact with clothes to prevent risk of ironmould, which explains why brass and wood are employed for interior vessels. The revolution of the cage lifts the clothes to a certain distance out of the water, into which they fall again, and in falling rub against each other as they are turned about. The cage rotates a few times in one direction, and then in the other, from twenty to twenty-five turns taking place in a minute. Pieces of wood or metal attached to the inside of the cylinder help to lift the clothes. There is thus no rubbing, but simply tumbling about and prolonged soaking in the liquor.

Flannels, flannelettes, and silks are of course not boiled. They are washed in a solution of

soap without soda in water only lukewarm. Boiling would turn them of a yellow tint, and flannels treated thus would shrink very much.

When the articles are dumped out of the rotary machines, they are sent to the *hydro-extractors* which partially dry the clothes in place of hand wringing. The "hydro" is a circular vessel or cage which is rotated several hundred times in a minute. The effect is to send the water flying by virtue of centrifugal force into an outer vessel, leaving the clothes fairly dry. They are then either ironed or hung in a drying room through which hot air is blown.

But in some laundries, another machine is made use of between the hydro and the ironer—a *tumbler*, or linen separator, to shake the articles apart, as they leave the hydro in a tangle. Human labour is thus saved even in this simple operation. Starching is done in the washing cylinders or in separate vessels.

Ironing and Drying Machines.—The ironing machines are made in many forms. The chief feature is a large cylinder or cylinders turned and polished on their exterior, and heated with gas or steam within. The work is carried along by these rotating cylinders and pressed between them, and beds of metal hollowed to fit the curves, and steam heated also. The cylinders are padded with layers of felt, and sometimes wrapped round with cotton sheeting. The padded surface yields slightly to pressure, due to seams, hems, and other differences in thickness of the work being ironed. It also acts frictionally on the article, carrying it round against the polished surface of the beds, the latter taking the place of the laundresses' flat iron.

The drying process is assisted by the ironing, due to the cylinder being heated with steam. The speed at which the work is carried through varies from about 15 ft. to 25 ft. a minute. As creases are liable to occur in ironed articles, the attendants have to look to this by passing the sheets, &c., in regularly. This too sets a limit to the speeds of the machines, for if they run too rapidly, there is not sufficient time to adjust the articles properly. Starched collars and cuffs are prevented from sticking by causing the ironing cylinder to travel faster than the bed on which the collar is laid. This skidding action also imparts the gloss which is desirable, corresponding to the action of the flat iron.

There are other machines for ironing collars, others for setting up the bands of shirts, others for damping starched seams and collars, so that they can be turned over and ironed, others for gophering.

Lead, Pb.—Comb. weight 206·4, is of much value as a metal, and as an alloying material. Its specific gravity is 11·3, its melting point 633° Fahr., its specific heat ·0314. It forms three valuable oxides: the monoxide PbO, litharge, and massicot. The first is produced at temperatures above the fusing point of the oxide, the latter at temperatures below. Litharge is used in the preparation of lead salts. Massicot is used in the manufacture of red lead, or minium, by the slow absorption of oxygen, with the composition $2PbO + PbO_2$. Lead dioxide, PbO_2, does not form salts with acids. Lead nitrate, $Pb(NO_3)_2$, is obtained by dissolving metallic lead, or the oxide, or carbonate in warm nitric acid. Lead chloride, $PbCl_2$, is prepared by adding hydrochloric acid to a strong solution of lead nitrate. Lead acetate, or sugar of lead, is obtained by dissolving massicot in aqueous acetic acid. Lead carbonate, $PbCO_3$, occurs native as cerusite. It can be produced by the addition of a solution of a lead salt to an excess of carbonate of ammonia. White lead is a compound of lead carbonate and lead hydroxide. Lead sulphate, $PbSO_4$, is prepared by adding sulphuric acid to a soluble lead salt. Lead sulphide, PbS, is galena.

Lead Smelting.—Most of the lead used is smelted from the ore *galena*, which is a sulphide of the metal. Galena occurs in many parts of England, Scotland, Spain, Saxony, and in the United States. It usually contains also a little silver in the form of a sulphide, which is often present in sufficient quantity to pay for its extraction.

Galena is smelted either in reverberatory, or in small blast furnaces, the methods varying with locality and with the character of the ores, whether rich or poor in lead, whether they contain much or little quartz. The ores are prepared for treatment by being broken up into small fragments, and by washing to separate the foreign matters intermixed therewith.

The reverberatory furnace in which smelting is performed is of a special type. It is provided with doors, three in number on opposite sides, through which the ore is turned about by the workmen. The hearth, lined with slags, is shaped so as to cause the bed to slope downwards from one side to the other in such a way that the melted lead shall collect into a depression against a tapping hole, which empties into a basin outside the furnace. There are four stages in the process of smelting; termed the first, second, third, and fourth fires, and it is completed in about five hours.

In the first stage, ore is spread over the hearth, and sufficient heat only is raised to roast the ore without fusing it. The result is that a large quantity of heat, but without oxygen, comes into contact with the ore upon the hearth, and an exchange of elements is effected, some oxygen combining with sulphur in the lead to form sulphurous acid gas, and some combining with the lead to form oxide of lead. A portion also of the ore takes up more oxygen, becoming converted into sulphate of lead. After awhile some dross or skimmings from a previous smelting are introduced into the furnace. This consists mainly of sulphur mixed with lead. The action of the oxide of lead and sulphate of lead upon this, results in the liberation of sulphurous acid gas, and the deposition of metallic lead, which is then taken out through the tap hole. Fresh surfaces are exposed from time to time, until a considerable quantity of lead has been reduced, and accumulated in the basin. A large quantity of unreduced galena remains in the charge, and this is further converted into oxide and sulphate by opening the doors and turning over the ore to expose it to the air. The *second fire* corresponds now with a raising of the temperature to a bright red heat, during which the sulphide of lead acts upon oxide and sulphate, causing a further reduction of lead to the metallic state, which runs out. During the period of the "second fire," quicklime is thrown into the furnace with the object of rendering the charge less fluid. At the same time the unreduced slags are spread over the charge, the temperature being at the same time slightly lowered. This is done in order to prevent any unreduced galena from sinking below the surface, where it would not be acted upon by the air, and it facilitates also the drawing off of the liquid lead. This lasts about an hour. During the period of the *third fire* the temperature is first raised, then lowered, the slags again spread over the hearth, and more lime thrown into the furnace. The lime favours the action of oxide of lead upon sulphide of lead, and by entering into combination with such silica as may be in combination with oxide of lead, leaves the latter free to act upon the residue of sulphide of lead yet remaining in the charge. During the period of the *fourth fire* the charge is raised to its highest temperature, the whole of the remaining lead is tapped out, and some more lime is added to the slags to dry them up, after which they are raked out, leaving the furnace hot and ready for another charge.

The scum on the surface of the metal in the pot is *paddled*, to liberate such lead as may be mechanically intermixed with it, and coal slack is strewn over the surfaces, and the gases therefrom ignited, so keeping the surface hot long enough to ensure the disengagement of most of the lead mechanically intermixed therewith.

The best lead is obtained in the Scotch blast furnace. This is not a furnace like that used for iron smelting, but is of small size. It is more like a forge, having a hearth about 18 in. × 12 in., and an internal height of about 24 in. It is arched over, and the lead fume is carried off through a long flue, to ensure the deposition of a large quantity of oxide and sulphate of lead, which is volatilised. In front of the hearth is an iron plate, or *work stone*, sloping away from the hearth towards an iron pot, into which the lead runs down a gutter channelled in the work stone. The blast enters at the back of the furnace.

The ore is roasted on the hearth of a reverberatory furnace before being introduced into the blast furnace. The roasting occupies about eight hours, some of the antimony and sulphur present being thereby expelled, and the ore rendered more porous. The ore is raked into water after roasting, and this breaks it up into small lumps suitable for treatment in the blast furnace.

The chief fuel used in the blast furnace is peat. On first lighting up the furnace, some of the *browse* or residue from a previous charge is introduced into the furnace. Some grey slag separates therefore on the work stone, and the browse is then thrown back, and its degree of fusibility noted. Lime is added at discretion until the required degree of fusibility is assured, and then the roasted ore is introduced with a little small coal. In about twenty minutes the charge is raked out on the stone, the grey slag picked out, and the residue returned to the furnace. Metallic lead runs into the basin, and so the process goes on for several hours.

The slags are reserved for a special smelting in the *slag hearth*, since they contain from one-tenth to one-fifteenth proportion of lead. The furnace is raised to a high temperature with blast; the charges consist of slags, coal ashes, and old hearths impregnated with lead. The lead is mainly reduced by the heated carbon of the fuel, and percolates into a deep bed of cinders in the bottom of the furnace, by which it is protected from the oxidising action of the air, and whence it runs away into an iron pot placed over a fire. The lead obtained from the slag hearth is of inferior quality.

But the lead obtained by smelting is *hard*, and not suitable for general use. The hardness is due to the presence of other metals, such as antimony, silver, copper, and iron, and these have to be eliminated by a process of calcination, or by *improving* the lead in a reverberatory furnace of special type. The hearth of the furnace is formed by a cast-iron pan, large and shallow, deeper at one end than the other, and having a gutter at the deeper end through which the metal is run out. The lead to be improved is melted in an iron pot adjoining the furnace, and ladled into the trough or pan. The flame from the fire-grate passing over the bridge is deflected by a low roof over the surface of the molten lead in the trough, and oxidises the foreign elements present, the dross or oxide being raked off from time to time, and the lead tested for purity. The time required will vary from a day to two or three weeks according to the amount of foreign elements present, antimony being the most difficult to remove.

Ores which contain sufficient silver to pay for its extraction are called *argentiferous* ores. The process of extraction employed is that known as Pattinson's, introduced in 1829. Without giving the details of the process, which lie outside our present subject, it will suffice to remark that it depends for its value upon the fact that if the metal which contains a percentage of silver is allowed to cool slowly, being stirred the while, the crystals of lead which are first formed will consist of nearly pure lead, the silver present crystallising with the lead at a later stage. So that the process essentially consists in melting the lead in a series of pots, and ladling out the successive crystals which form, leaving the lead behind richer in silver. The removal of the silver also improves the lead itself, because most of the antimony and copper which happen to be present either remain behind with the silver, or are oxidised during the process. Pattinson's process effected a revolution in the lead-smelting trade, since it not only improved the quality of the metal, but it permitted of the extraction of silver from ores which could not previously be profitably worked for its extraction. Previous to 1829, ores containing less than about eleven ounces of silver per ton could not be profitably smelted for the extraction of silver, because it was necessary to oxidise all the lead in order to obtain the silver, the lead being reduced afterwards by smelting. Now it pays to obtain silver from argentiferous ores containing only two parts of silver in the thousand. It is because of the unreduced silver which much of the old sheet lead contains, that it is bought so eagerly when opportunity offers.

Lead Screw, or **Guide Screw.**—The master screw in a lathe, which is the first element, whence the cutting of screws of nearly all pitches is calculated. Its pitch is one that admits of ready subdivision, the most frequent being two to the inch in the larger lathes, and four to the inch in the smaller. Sometimes lathes have three to the inch, but these are not so convenient. Decimal pitches and metric pitches are becoming more common in American lathes than formerly. *See* **Screw Cutting**.

Lead screws are never made with vee threads, but have either square threads with the edges

and roots slightly rounded, or threads with a slight taper to the sides, or threads with convex edges and concave bottoms. Absolutely square threads are impracticable, because the clasp nut could not be readily thrown into engagement, hence the rounding imparted to them. But the sub-angular section, or the fully rounded section are preferable, because in these the clasp nut fits closely down into the threads when both are worn, and so maintains a tight fit. With the first named, when wear occurs, the fit is slack against the sides of the threads, and the pressure takes place in the roots and points. This is the reason why wavy marks show on some turned work done under such conditions.

The position of the lead screw is generally in front of the lathe bed. In the older designs the screw stands out away from the bed by from 3 in. to 4 in., and is thus unprotected, besides involving an excessive overhang of the slide-rest carriage. At present the tendency is to imitate the American design, placing the lead screw closer in, and the feed rod over it, instead of locating it as a *back shaft.* In the Sellers' design, and some others, the lead screw is located within the bed; in the first-named lying in a recess formed within and underneath the front shear, where it is absolutely protected. But the clasp-nut thread is then only an arc of the circle, and is thrust out and into engagement horizontally. In others the screw lies centrally between the shears, and though not protected as in the case just noticed, its pull on the carriage is rather more central. Protection is often afforded to screws by long guards attached to the carriage, and extending over the screw to right and left.

Heavy lead screws have to be supported at intervals by means of bearings away from the ends. In some designs tumbler bearings are used which are knocked aside by the traverse of the carriage, and return into position directly it has passed, Fig. 83.

With few exceptions lead screws are rotated in their bearings. Exceptions occur in the heavy Hulse lathes, in which the screws are fixed, and the clasp nuts are rotated by gears. In another design, that of De Fries, the screw is not an independent full-threaded screw, but its section is an arc of a circle only, and it is screwed to the lathe bed underneath the front shear. The function of the clasp nut is taken by a worm which is rotated in the screw, and so pulls the carriage along.

Lead screws are in one length, except in some types of gap lathes, fixed, or movable. Instead of placing the screw so low down as to permit it to clear the bottom of the gap, or having to withdraw it to do work in the gap, when placed high up, the screw is stopped short at the gap. It is then driven by gear from a central shaft situated lower than the bottom of the gap.

The wear on lead screws being objectionable,

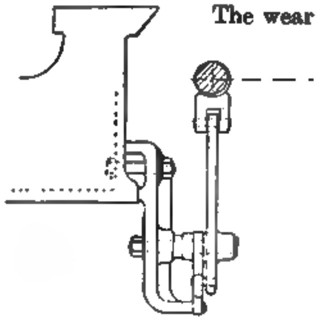


Fig. 83.—Tumbler Bearings for Lead Screw.

in many cases provision is made for reversing the screw in its bearings to bring each end into service. The lead screw should be reserved for its special duty of cutting screw threads, because if employed for plain turning its wear is accelerated. To avoid fitting a separate feed shaft the screw is sometimes key-grooved or splined throughout its length. This is economical, but not good practice, and is not adopted by the majority of firms. A practice which is growing, and which has advantages, is the driving of lead screw and feed rod from the same set of change gears. The screw and rod are geared together in a ratio of from 3 to 1 to 5 to 1, so that the rod runs faster than the screw in that ratio for any combination of change gears. Either is thrown into or out of connection by sliding gears operated by a lever.

Each is then kept for its special function; the relative rates of each are known, and either turning or screw cutting can be done by a rapid change, and the turning feed is positively driven.

The lead screw, serving for the cutting of hundreds of possible threads by combinations of change wheels, is a valuable mechanical element. But in these days of specialisation the province of the lead screw is invaded, simply because it is not the best possible device for some classes of work. If one were cutting long threads all the time, and the pitches required were not changed frequently, then nothing could be said against the utility of the lead screw. But what happens is that short screws mostly predominate, just as short turned jobs do, and that screws of different pitches come in rapid succession in the practice of the general shops. In these shops it is impossible to specialise much around screws, the work of stud and bolt making excepted, and perhaps that of gas threads. The lead screws therefore get worn more near the head stock than near the tail end, and changes of wheels are required more often than is desirable or economical.

From this point of view the design of the brass-finisher's chasing lathe solves the difficulty in short threads. The screwed hobs and hinged combs permit of cutting short threads in quantity with the minimum of fixing up, without lead screws or change wheels. A device derived from this is to put a hob in the form of a sleeve on a shaft in front of the lathe, taking the place of the lead screw. An example of this kind is familiar in the lathes by A. Herbert, Ltd. The hollow screwed sleeve is mounted on a shaft driven from the lathe spindle through change gearing. It is removable at the right hand by fitting a sleeve to the shaft at the right, taking its bearings in a bracket bolted to the front of the lathe bed. On removing the sleeve by withdrawing it endwise through its bearings in the bracket, the screwed sleeve can be withdrawn in the same fashion and another substituted.

Leaky Tubes.—Few subjects bearing on boiler engineering have elicited so much controversy and discussion as that of leaky tubes chiefly in marine boilers. Scores of remedies have been proposed and tried; chiefly ferrules of various kinds, protective fire-proof coverings, various arrangements of the tubes themselves, reductions in the thickness of tube plates—giving greater elasticity to the plates; the prevention of currents of cold air from impinging on the tube plates, different methods of expanding the tubes in their plates, &c.

The trouble of leaky tubes is not due alone to the high temperature to which their ends are subjected in the fire-box or in the combustion chamber. Experiments and observation have proved that the highest temperatures ever attained do not loosen the tubes. When tubes become loosened and leak it is always due to their being suddenly cooled down from a high temperature. When the furnace doors are opened, there is a rapid inrush of cold air sweeping in under pressure at a rate perhaps of 60 or 70 feet per second on surfaces at a temperature probably of something like 3,000° Fahr. The thin tubes shrink at once, and the evil increases progressively. Such being the case, it is obvious that separating the combustion chambers of the several furnaces, and shortening the length of fire-grate—which are devices that have been adopted in the Royal Navy—do not touch the real cause of the evil. From this point of view the closed ash-pit system possesses obvious advantages over the closed stokehold. In this the draught is shut off from a furnace that is being charged, by the opening of the doors, and the only draught which enters is the relatively small amount of natural draught induced by the funnel.

Some of Sir John Durston's experiments were made on an experimental boiler to determine that temperature of the tube plate at which overheating, such as causes leaky tubes, takes place. It was ascertained that a tube plate, to be overheated sufficiently to make the tube joints leak, must be raised at least to the temperature of melting zinc, viz., 750° Fahr. At the temperature of molten lead, viz., 630° Fahr., the tubes remained practically tight. At a red heat, equal to about 1,400° Fahr., all the tubes leaked, and there was no difference in the behaviour of steel, brass, or iron tubes. The steam pressures in these experiments varied between 80 and 100 lb. Sir John Thornycroft

thought that the joint between the tube and plate offers great resistance to the transmission of heat; and instanced the case of a bar cut in two, and then butt-jointed closely, the effect being to ruin the heat conducting power of the bar.

Probably one cause of the evil of leaky tubes when forced draught is used is this. The nests of tubes are placed right over the furnace crowns, and the steam, rapidly generated, can only get away with difficulty from between the narrow inter-tube spaces, so that probably portions of the tubes at intervals throughout their whole length, are sometimes bare of water. The hot gases passing through the tubes then tend to lengthen them, and so they will be subject to alternate lengthening and shortening, due to the variations of temperature.

The two theories, then, which seek to explain the cause of leaky tubes under systems of forced draught are: the one which attributes it to the inrush of cold air on opening the furnace doors, the other to the too rapid generation of steam and consequent imperfect contact of the water with the tube plate, and with those ends of the tubes next the tube plate. The truth probably lies with both. The inrush of a large body of cold air in closed stokeholds cannot fail to cause sudden and severe contractions of the highly heated tube ends and plate. And there is little doubt that at the high temperature of the combustion chamber, from 3,000° to 4,000° Fahr., the water must often be thrown off from contact with the tube plate by the rapid formation of steam, and then overheating of the plate and tube ends is as certain to occur as if the heat transmitting power of the plate were impaired by the presence of heavy scale.

If the admission of cold air were the only cause of leaky tubes, then the evil could be averted either by the adoption of Howden's system, or by ferruling the tube ends. But if the too rapid formation of steam due to the intense rate of combustion be the only cause, then apparently the remedy, short of abandoning very high forced draught pressures, would be to adopt methods of circulation, by means of which the water should be forced into contact with the tube plate, and the steam displaced, and caused to leave the plate immediately on its formation. Spacing tubes wider would increase circulation, but this means a larger number of tubes and increased size of the boiler.

The double-ended type of marine boiler, with a common combustion chamber to all the furnaces at both ends, has given vastly more trouble with leaky tubes and bad circulation than the single-ended boiler, with a water space at the back end of the combustion chamber. Single-ended boilers have given very little trouble even under forced draught. The circulation in the latter is better than in the former.

Much injury is sometimes done to the tube plates and tube ends in the combustion chambers of marine boilers by the too frequent or prolonged opening of smoke-box doors, done in order to check the draught, and lower the steam. Even with natural draught the operation of cleaning or clinkering the fires is fraught with danger to the tubes and plates. In each case the inrush of cold air on the heated and expanded plates and tubes often results in leakage of a more or less serious character.

Whether cold or hot air is used in forced draught can scarcely affect the question of leaky tubes. The hot air is low in temperature by comparison with the temperature of the combustion chamber, and its chief advantage lies in the saving of a certain quantity of heat units which would otherwise pass off with the waste gases. But the sudden inrush of cold air upon the opening of the furnace doors, is prevented by the device of shutting off the blast on the opening of the doors.

Methods which have been adopted to prevent the leakage of tubes are: rolling or expanding the tubes with a shoulder inside the tube plate; beading tubes over the tube plate; expanding tubes quite parallel; fitting common ferrules into the tubes; doing away with stays between the boiler shells and the tops of the combustion chambers. In torpedo boat boilers of the locomotive type the experiment has been tried of plastering the tube plate on the fire side with a non-conducting composition. Another plan has been to ferrule the tubes with cap ferrules of fire-clay, to afford protection to the tube ends and a portion of the plate. These were not permanent protections, being soon destroyed,

but they demonstrated what was suspected, that the leakage of the boiler tubes was due to overheating of the tube plates and tube ends.

Circulating plates have been fixed into boilers with success, both with a view to reduce priming and to prevent leaky tubes. Several different arrangements have been adopted, the aim in each case being to maintain a constant movement throughout the water in the boiler. It is obvious that in a multitubular boiler the large extent of tube heating surface is gained at a sacrifice of circulation, on account of the intense generation of steam preventing the water from descending freely. Portions of the water are carried upwards, entangled with the steam, and cause priming, and the tube plates are probably often left bare, because that is the locality where the most intense generation of steam takes place.

The proposal has been made by several engineers to thicken the tube plates with bosses around the tubes, the bosses being on the water side, the idea being to retain the advantage of thin tube plates with increased bearing surface for the tubes. Regarding the matter of leaky tubes from the point of view of the circulation, many engineers think that if the circulation were improved there would be little or no trouble experienced. From this point of view, trying to remedy the evil by using thin plates, or by protecting them with ferrules, or by providing as much elasticity as possible in the tubes and plates does not touch the root of the evil. For if the circulation were improved, the essential basis of the trouble would be attacked and conquered. As an expedient to keep the water in better contact with the plate it has been more than once suggested to incline or cant the boiler slightly, and it has been pointed out that this would facilitate the disengagement of the steam bubbles as they are formed, each layer arising at a different level from the rest, and having therefore an unimpeded course upwards.

That tubes are crushed in their holes on the fire side of the tube plate is evident, because they become quite loose there. Either this must happen, or the holes in the tube plate must expand, which is contrary to what is known of the contraction of metals under alternate heating and cooling. The tube end is crushed partly by its own expansion, which is prevented from taking place by the less easily expanded tube plate, and partly by the contraction of the tube plate when the latter cools. When tubes work loose in their plates that affords an opportunity for dust, dirt, scale, and grease deposits to form, and these prevent the rapid conduction of heat between the tubes and plates, and so aggravate the evil of unequal contraction. Since the different expansions of different tubes stress the tube plates of marine boilers, it has been suggested by more than one engineer to impart a slight initial curvature to the tubes, so that under varying stresses the cambers of the various tubes may accommodate themselves thereto. Actually this plan was tried by Mr Stroudley some years ago in locomotive boilers, but the practice was discontinued.

Least Common Multiple.—One number that contains another an exact number of times is said to be a *multiple* of that number. Thus, 6 is a multiple of 3 or of 2, but not of 4. The number 12 being a multiple of both 6 and 4 is called a *common multiple* of 6 and 4; similarly 24, 36, 48, and so on, are common multiples of these two numbers, but 12 is clearly the *least common multiple*, abbreviated L.C.M.

As pointed out under **Fractions**, it is necessary to find the L.C.M. of the denominators of a series of fractions which have to be added or subtracted. The rule for finding the L.C.M. is as follows:—Place the numbers in a line and strike out any of them which are factors of the others; divide those that remain by any prime numbers which are contained in more than one of them, placing the quotients obtained and the undivided numbers in the line below. Continue the process until no two numbers are left having a common measure greater than unity. Then the product of all the divisors and the numbers left is the L.C.M.

Examples:—

$$\begin{array}{r|rrrr} 2 & \cancel{4}, & \cancel{8}, & 12, & 16 \\ \hline 2 & & & 6, & 8 \\ \hline & & & 3, & 4 \end{array}$$

L.C.M. = $4 \times 3 \times 2 \times 2 = 48$

$$\begin{array}{r|rrrr} 3 & 15, & 35, & 63, & 72 \\ \hline 3 & 5, & 35, & 21, & 24 \\ \hline 5 & 5, & 35, & 7, & 8 \\ \hline 7 & 1, & 7, & 7, & 8 \\ \hline & 1, & 1, & 1, & 8 \end{array}$$

L.C.M. = $8 \times 7 \times 5 \times 3 \times 3 = 2520$

Therefore 48 is the least number into which 4, 8, 12, and 16 may be divided without a remainder, and 2,520 is the smallest number containing each of the quantities 15, 35, 63, and 72.

Leather.—Employed for various engineering purposes, including belting, gears, hydraulic machinery, &c., and treated under different headings.

Lens.—So important a part does photography play nowadays in engineering establishments that many large firms find it necessary to add a studio to the factory equipment, and chief among the apparatus to be purchased is the photographic lens.

The lenses used by the photographer are "spherical," that is, their surfaces are parts of the surfaces of spheres. They are also "converging" lenses, the parallel rays of light being refracted and made to converge to a point on the other side of the lens. The modern lens is however a very highly complicated combination of many lenses so arranged and cemented together as to correct certain optical defects, and so combine as many desirable properties as possible.

The main points to consider in the purchase of lenses for engineering photography are:—

(*a.*) Focal length of lens. Roughly speaking this is the distance from the lens to the focussing screen, when a distant object is sharply focussed. In practice, the focal length of the lens considerably affects the size or rather scale of the picture. For average work a lens is used whose focal length is about the same as the length of the diagonal of the plate used. But where such a lens at a certain distance, say, from a traveller would fail to include the whole of the structure, a lens of shorter focus would easily do so on the same plate without altering the position of the camera. The scale, of course, would be smaller; the angle of view embraced would be greater. It is thus evidently out of the question to expect one lens of a certain focus to grapple with all the difficult tasks demanded by engineering photography. There is, perhaps, no other kind of work in which the camera has so frequently to be operated in such confined quarters. Hence, in addition to a lens whose focal length is about one and a third times the longest side of the plate, it is necessary to have one not more than three-quarters the length of the longest side. A wide-angle lens constructed for an angle of 90° will be sufficient for most cases, although there are lenses on the market embracing the enormously wide angle of 135°, and with a focus of 4¾ in., covering a plate measuring 12 in. by 15 in. At the same time a short focus lens should never be used when it is possible to work with one of longer focal length, because of the exaggerated perspective alluded to under **Camera.**

(*b.*) *Depth of Focus.*—This means the power of the lens to render objects at varying distances, *i.e.*, in different planes, equally sharp on the plate. Thus, in focussing a boiler, when one end appears sharp on the screen, the further end may be badly out of focus. Another lens, however, may render the whole boiler equally sharp throughout its length. Evidently, then, this is a very desirable property in a lens for engineering photography, for no tool, machine, crane, or other structure can be too sharp or clear even to the smallest detail. Depth of focus is governed by two things — the focal length of the lens, and the aperture of the lens. The longer the focal length of the lens, the greater is the depth of focus, so that not only for reasons of perspective, as stated in the preceding paragraph, but also for the purpose of getting all parts of a machine sharp, should the engineer's photographer use the longest possible focus circumstances permit.

Depth of focus is also increased by decreasing the size of the aperture of lens. In the case of the boiler mentioned above, the entire body would be in sharp focus by decreasing the lens aperture with the iris diaphragm. This, however, brings in the question of:—

(*c.*) *Rapidity.*—The rapidity of a lens does not concern the engineer's photographer so much, for example, as it does the press photographer. Cranes, lathes, saws, dynamos, engines, and so on, are incomparably better "sitters" than animated bipeds or quadrupeds. Yet from another point of view rapidity does come into the question, for unless the object be out of doors, the light that penetrates grimy factory windows will be but

feebly actinic, and if a small stop be used to ensure good definition, the exposure will be unduly prolonged. But if the time and position be such that the apparatus will suffer no disturbance, length of exposure will be of no great consequence. The rapidity of a lens depends on the relation between the diameter of the aperture and the focal length. Thus, "F8" means that the aperture of the lens is one-eighth of the focal length, and the larger this aperture is in comparison with the focal length, the more rapid (and more costly) will be the lens. A lens of full aperture F8 is sufficiently rapid for engineering work.

As regards the degree in which various types of lenses satisfy the points mentioned above, the "single" achromatic lenses are entirely out of the question owing to the distortion of straight lines into curved ones; a wide-angle "rapid rectilinear" by a reliable maker is a good all-round lens suitable for most work; a much more expensive but far superior lens is the "anastigmat." In this lens, rapidity, quality of definition, angle of view, and equality of illumination are all superior to those of the rectilinear lens. At present, the anastigmat marks the high-water mark of photographic lens production.

When not in use, lenses should be kept from dust and light in cases or wash-leather bags in a dry place, and should occasionally be dusted with a camel-hair brush, the combinations of symmetrical lenses being unscrewed and separately dusted. *See* **Photography — Workshop.**

Level.—Truly horizontal; or flush; in one plane. An instrument by which the horizontal position is tested.

The Spirit Level.—This derives its name from the alcohol which nearly fills a closed tube of glass,—the *bubble tube*. The very small portion left unoccupied by the spirit produces the bubble, which is in the centre when the tube lies horizontally. To cause it to move to the centre, the tube is enlarged about the middle portion of its length. In some cases the enlargement is bodily, the diameter externally and internally being greater there than at the ends. In others the tube is parallel, but the central internal portion is enlarged by grinding. The ends are sealed. The tube is mounted in a stock of wood or metal, with considerable variations in design.

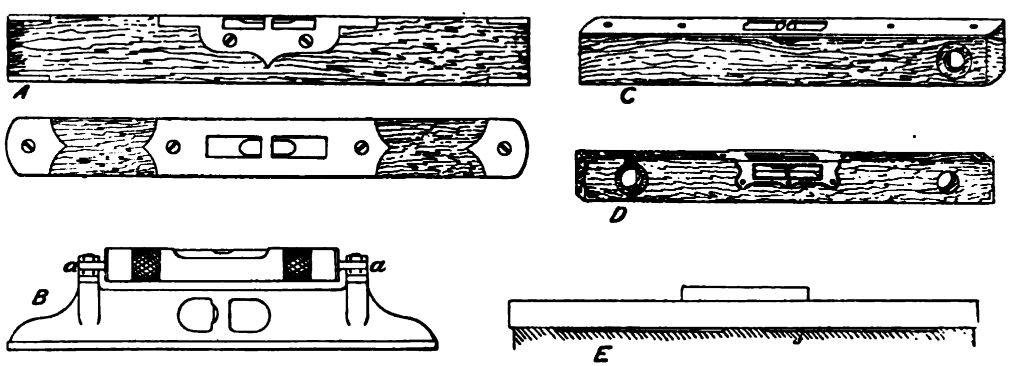


Fig. 84.—Levels.

The levels in wood stocks, Fig. 84, A, are used by wood-workers and moulders; the more durable class for machinists are mounted in metal, B, and the best of these contain provision for screw adjustment at *a*, *a* to compensate for unequal wear of the base. A level which is not quite true can, however, as a makeshift be made to read truly by reversing it, end for end, when the bubble will run to an equal distance out of centre on opposite sides of the middle bar.

When work stands high up the bubble can only be seen by getting up to it. In such cases those levels are useful in which there is a side sight, as in A, C, and D, as well as the one on top. Many levels combine bubbles at right angles, C, D, so that the same instrument can be used for testing vertical and horizontal faces.

To lessen the wear on the bottom, and also

to enable the level to cover a long piece of work, it is often permanently attached to a long parallel straightedge. Or, with the latter object, the work is bridged with a straightedge and the level laid upon it, E.

The Y-*Levels.*—These are used by engineers in taking surveys of parts distant from each other. They vary in details, but consist essentially of a spirit level, compass, levelling screws, and a tripod stand. The telescope rests in the vees, or Y-shaped supports, hence the name, and is clipped therein, but the clips can be removed. The telescope has its eye piece at one end, which may be protected by a shade from the glare of sunlight. At the other end is the object glass, and between the two is the diaphragm, crossed with spider webs, or with lines ruled on glass or *stadia points.* The object of these is to centre a distant object by reference to the intersection of the fine lines, provision being made with fine screws for adjusting them. The lines, hairs, or otherwise are kept as nearly as possible in vertical and horizontal positions. Provision is made by nuts on the stem of one of the Y bearings for vertical adjustment of the telescope. The spirit level has provision at one end for vertical adjustment by means of nuts. The tube has lines marked across it to indicate the central position of the bubble. The entire head can be swung round to any point of the compass and clamped, by hand movement only, or the same being supplemented with a fine adjustment by a tangent screw in some instruments. The instrument is supported on a tripod head having two plates, the lower one attached to the tripod legs, the upper adjustable, with three or four levelling screws.

Levelling Block.—The common levelling block is a massive plate of cast iron, from 2 in. to 3 in. thick, and several feet long and wide, and planed on the top face. These blocks are stiffened with flanges cast round the edges of the lower face. Numerous holes are frequently cast through the plate to afford means of attachment for various blocks, and holding down appliances. Two or more blocks may be bolted together by their flanges to make one large one. The faces become convex after long service, and have to be corrected by re-planing. Levelling blocks are supported on timber blocking.

Levers.—A lever is a rigid bar which turns about a point called the fulcrum; the parts of the bar on each side of the fulcrum are called the arms. By applying a force P at one point in the lever, a weight W may be raised or a resistance overcome at any other point. If the lever be a straight rod, P and W act perpendicularly to the arms.

Levers are divided into three classes according to the position of the fulcrum with respect to the power and weight.

(1.) P, F, W (Fig. 85).—The fulcrum lies between the power and weight. Levers of this class are seen in the crowbar resting on a block between the hand and the weight; the handle of a pump; a see-saw; a lock gate; a garden spade; a pair of scissors (a double lever); a poker when resting on a bar and raising coal in the fire. The bascules of the Tower Bridge are levers of the first order, the portion visible being one of the arms.

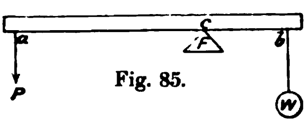


Fig. 85.

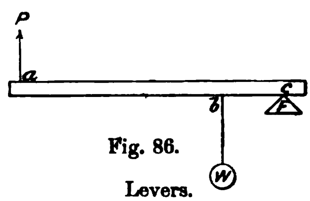


Fig. 86.

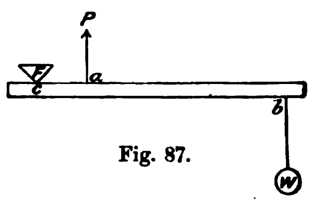


Fig. 87.

Levers.

(2.) P, W, F (Fig. 86).—Here the weight occupies the middle position. Examples:—a wheelbarrow (F, at the axle); a crowbar when the point is on the ground; a rowing boat (F, the blade in the water, P, the hands, W, resistance at rowlocks); a pair of nut-crackers (double example).

(3.) F, P, W (Fig. 87).—The power here lies between the fulcrum and weight. Examples:—the treadle of a lathe; a pair of tongs (double); the forearm when raising a weight in the hand.

In a lever, the power multiplied by its arm

or distance from the fulcrum equals the weight multiplied by its arm. *See* **Moments.** So that in the diagrams, $W \times bc = P \times ac$, and $\frac{W}{P} = \frac{ac}{bc}$. If the force P applied to the lever is less than the resistance W, the above fraction will be greater than unity, and the lever is said to work at a mechanical advantage. If W is less than P, the lever works at a mechanical disadvantage. And since $\frac{W}{P} = \frac{ac}{bc}$ all levers will be mechanically advantageous according as ac is greater or less than bc.

In levers of the first class it is evident from the diagram that ac may be greater than, equal to, or less than bc according to the position of the fulcrum. Therefore this lever may possess a mechanical advantage or disadvantage, or the force may be equal to the resistance.

In the second class, ac is always greater than bc, and hence they are always mechanically advantageous.

In the third class, ac is always less than bc, and so levers of this type are always mechanically disadvantageous. But though much force is required to overcome a little resistance, these levers are always advantageous in another sense—the weight is moved through a greater space than the power itself moves.

From the equation, $W \times bc = P \times ac$, either the power necessary to raise a weight, or the weight which may be raised by a given power may be calculated when one or the other is known. The pressure on the fulcrum in class 1 is equal to power + weight; in class 2, weight − power; in class 3, power − weight.

The three types of levers just described abound in machines, tools, and engineering structures, sometimes in such a disguised form that they may not be recognised as levers. They will be seen in foot brakes, toothed gears, the engine beam, the air-pump lever, cranks, eccentrics, the steelyard, the lever safety-valve, cams, clasp nuts, and the drive of the axle turning lathe.

In bent levers the lengths of the arms are not taken, but instead the lengths of perpendiculars measured from the fulcrum to where they meet the lines of direction taken by the forces.

Compound levers are a system in which two or more levers act on each other, the short arm of one acting on the long arm of the next. Examples occur in weighbridges, and testing machines.

Lewis, Lewis Bars.—A device for holding concrete blocks during setting, with provision for ready release, being an alternative to external clips. Two bars are necessary, one near each end of the block, passing through holes moulded in it, and being carried on a lifting beam.

A common practice is to make the bar of a tee shape at its lower end, to fit in a tee-shaped recess moulded in the block at the bottom of the holes. In the direction at right angles with the tee the hole is wide enough to allow the tee and the shank to pass. It is thus turned at right angles for holding, and back for release. This requires the services of a diver to insert and remove a pin by which the bars are secured to the beam. A *self-releasing* arrangement comprises two bars connected with short links, so that they move closer to, or farther from each other, similarly to the sides of a parallel rule. These fit in a tapered hole in the block, being pulled apart when the weight comes on. When the block touches the bottom and the beam is lifted, one of the bars is pulled inwards by a chain which connects it to the beam, and so with its fellow comes out of the hole.

Licker.—A device for lubricating a moving part from a lubricator which is stationary. Thus a crosshead in a large engine is supplied while moving by a licker on the oil box, which wipes off a drop of oil at each stroke from the end of a pipe coming from the fixed lubricator, and over the oil box on the crosshead, which drop then passes into the oil box and down to the crosshead pin.

Lifters, or S-Hooks.—Rods from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. square, of a few inches in length, and turned round at each end; one hook to embrace the top edges of the bars of a moulding box, the other going down into the mould to help to sustain the sand. Examples are seen in many of the mould sections in these volumes. They are swabbed with clay wash before the sand is rammed about them. The quickest way to mould lifters is to make a pattern consisting of

a stout piece of board, say 1¼ in. thick, with a couple of stiff battens on the back, and having three strips of wood nailed on to form the lifter outline. Several such being nailed on the board, a level sand bed is struck off with winding strips, and straightedges, and the lifters are moulded by simply bedding in the plate, by beating it down into the sand, until the face of the board is level with the bed face. The bedding-in is done by beating the stiff battens on the back with a wooden mallet.

Lifting Magnets.—Though the application of the electro-magnet to hoisting purposes is comparatively recent, the advantages derived have caused the system to develop rapidly. The magnet takes the place of sling chains and hooks, and in most cases does away with the services of a slinger or ground man. The magnet is suspended from the crane hook, and a flexible cable conveys current to the magnet coils, a switch being placed in the crane operator's cage. The magnet is lowered upon the iron or steel objects to be lifted, current switched on, and hoisting up done. The magnet clings to the work, which constitutes a keeper across the poles. The attendance of a slinger is only necessary when pieces have to be turned about, or adjusted after lifting.

Lifting magnets have developed along special lines, rendered necessary by the peculiar conditions under which they work. There is the rough usage in contact with castings, &c., the effects of damp, and continual strain on the coils due to the rapid switching on and off of current. The Wellman magnet, brought out in 1895, was of oblong form, a style still employed for handling plates and other flat objects. But for pieces such as pig, castings, scrap, &c., a more suitable design is used, of circular form, and hollowed underneath to bring the central pole-piece above the outer encircling pole. The effect of the material lying partly within this pole is to greatly increase the magnetic effort. The casing is of cast steel, and the periphery is ribbed to provide for the rapid radiation of heat from the coils. The lifting capacities vary according to the class of material. Thus a magnet 51 in. diameter, weighing 5,400 lb., and consuming 27 ampères at 220 volts, working out to 8 E.H.P., will lift a skull-cracker ball of 20,000 lb. weight, but on heaps of pig the magnet may only pick up from 1,150 to 1,350 lb. Billets or slabs are handled from 900 to 6,000 lb. Scrap of various kinds, including wire, tin plate, croppings, &c., ranges from 500 to 1,100 lb. picked up.

In addition to the objects enumerated above, magnets are suitable for handling rails, plates, pipes, shafts, castings and forgings, loose materials, as rivets, bolts, kegs of nails, &c., and machines or parts. Plates require, if long and flexible, two or more magnets, suspended from a beam hung from the crane chain. Auxiliary hooks or clips are sometimes used after a plate has been picked up by a magnet, as a safeguard if the plates have to be carried over men, although the chances of failure of a magnet have been proved by experience to be very small.

Fig. 88.—Section through Lifting Magnet.

Fig. 88 shows a sectional view of a magnet by the Sandycroft Foundry Co., Ltd., from which it will be seen that the outer casing has a lug and shackle for lifting by, while the two pole-pieces, held in the casing by set-screws, are encircled by the coils, protected by plates covering in the spaces between the poles and the case. Figs. 89 and 90, Plate VI., show two applications of magnets, the first lifting a pipe by contact with its circular body only, the second a machine table. In Fig. 89 the crane is a hand-operated one, fitted to convey the current to the magnet.

Lifting Plates.—Plates attached to foundry patterns, by means of which the patterns are withdrawn from their moulds. They usually combine provision for preliminary rapping.

In small patterns, and large ones also from which few moulds are required, such plates are often dispensed with; the rapping and lifting being both done with a spike or vent wire driven into the wood. But that is not suitable for standard work, the patterns for which have to be preserved with care as long as possible. Hence one reason for the use of rapping and lifting plates; another being that a spike does not afford a secure hold in timber against the pull of a heavy pattern, or a deep draw.

If pattern webs are too thin to permit of letting in plates flush, they may be screwed on the face, D; or, with plates let into thin stuff, the screws may pass through the pattern into blocks beneath, E, the impressions of which are stopped off in the mould. A good hold for the screws is essential in any case, because the shocks due to rapping would otherwise loosen them.

Plates are arranged to lift a pattern in a level plane. Small patterns may have one plate only in the centre, F, for rapping or lifting, in

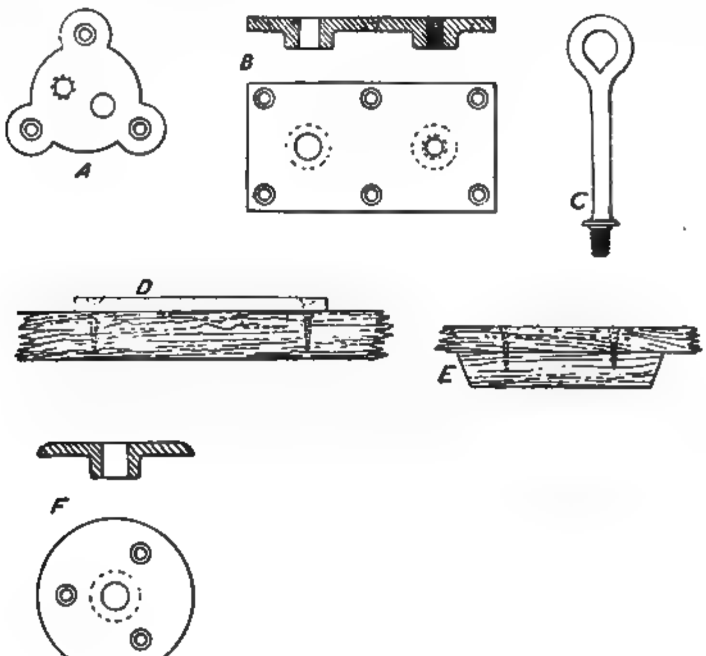


Fig. 91.—Lifting Plates.

The plates supplied to the trade are mostly of malleable cast iron, Fig. 91, A, B, having a plain rapping hole, a tapped lifting hole adjacent, and countersunk holes for wood screws for attachment to the pattern. The plates are generally sunk in flush with the surface of the pattern. In some of the larger sizes, thickening up around the holes is done by bosses, B, which are let into centre-bit holes, but small plates are generally flush on both sides. Plates are square, oblong, plain circular, or circular with lugs for the screw holes, and lifting screws C are supplied.

larger ones plates must be distributed, but always to ensure an even lift. Very heavy patterns may have the lifting plate on the bottom, G. In hand lifting, requiring the services of more than one man, each watches his fellows and lifts in unison. When lifting is done by the crane, the cross is used, and the sling chains H are strained to get an even tension on each previous to withdrawal.

Lifting Straps.—These, Fig. 92, are used on deep patterns where the friction of the sides is severe, and for the withdrawal of which lifting plates could not be depended on to hold

Fig. 89.—MAGNET LIFTING PIPE. Fig. 90.—MAGNET LIFTING MACHINE TABLE.
(Sandycroft Foundry Co., Ltd.)

Fig. 98.—PRESSED STEEL SLEEPERS. Fig. 99.—SADDLE TANK LOCOMOTIVE.
(W. G. Bagnall, Ltd.)

Fig. 100.—END TIPPING WAGON. Fig. 101.—OPEN-SIDED WAGON FOR HOT COKE.
(W. G. Bagnall, Ltd.)

To face page 83.

sufficiently. These are made of hoop iron, or flat bar iron, screwed down the pattern sides. They are turned over at the lower end, and have a lifting eye at the top to receive the

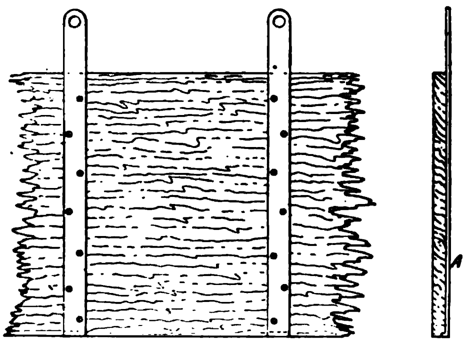


Fig. 92.—Lifting Straps.

hooks of sling chains. They may be screwed on the face simply, A, or let in flush and screwed, B.

Lift Pump.—Sometimes called the common, suction, or atmospheric pump. It depends for its action on the pressure of the atmosphere. The principle is shown in Fig. 93. A is the cylinder or barrel in which the hollow bucket B works up and down. At C is a valve only opening upwards. D is another valve sometimes distinguished by the name "suction valve," opening similarly. The valves are prevented from rising too high by the arch of the bucket in one case and by the stop piece at E in the other case. The bucket is made air-tight by leather or other packing.

When the bucket is raised the air in the lower part of the barrel is rarefied; consequently the valve D is pushed up by the water below, which enters to fill the partial vacuum. As the bucket descends, the suction valve closes, and the bucket valve opens to allow of the escape of the air under compression. Thus the air becomes more and more exhausted at each stroke until water only fills the cylinder. Water then flows through the valve D at each up stroke, and through C at each down stroke, and as the piston is raised, the water above it will be forced through the discharge pipe.

There is of course no "suction" in the operation. The water rises owing to the weight of the atmosphere. It follows, therefore, that the lift pump cannot raise water to a greater height than that of a water barometer, or 34 ft. But it is impracticable to place the suction valve at a greater height than 26 ft. above the level of the water in the well, owing chiefly to leakages past the valves and defects in fittings.

The pull on the pump rod at the upward stroke is equal to the weight of a column of water with base equal to the cross sectional area of barrel, and having a height equal to that of the water being raised, reckoned from the level in the well.

Fig. 94 shows a lift pump of a different type, crank-driven, using cranks of two or three throws. The barrel A is of brass, or in many cases of iron, brass-lined. The bucket B has a retaining ring C for the leather, with a central boss and ribs attached, and screwed up to the end of the rod. The valve D lifts against the pressure of a coiled spring and abutment piece. The foot valve E lifts against a similar spring, the abutment piece of which is screwed into

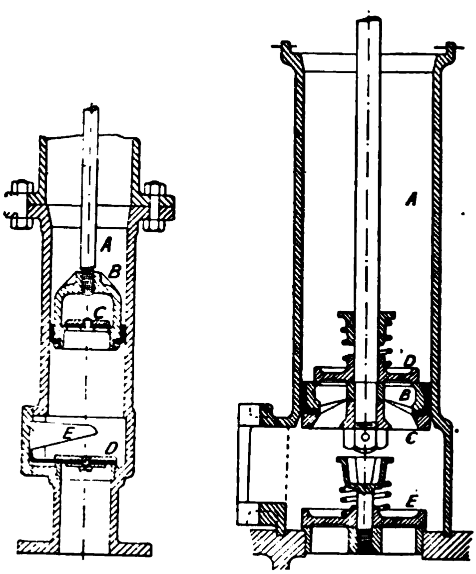


Fig. 93. Fig. 94.
Lift Pumps.

the seating. This type of barrel is united to a suction box below and delivery box above common to the two or three barrels which may be used.

Lifts.—Designates any rooms or cages which are elevated and lowered in a perpendicular, or an inclined direction. They are used for goods of all kinds, and passengers, are actuated by hand, by steam, water, and electricity.

Belt-driven lifts, actuated from a steam or gas engine, were formerly more common than any others, the small endless rope, hand operated, for light lifts only excepted. They are still largely employed, though their place has been invaded by other agencies. The drive is by a fast pulley with loose pulley adjacent, and the rope is coiled round a drum. The connection between the two is made by a worm and worm wheel. A hand brake is fitted, the cage is counterbalanced by a cast-iron weight, and runs between guides of hardwood, or of iron. The cage is of the suspended type.

The hand-power lift is raised and lowered by an endless rope running in pulleys with vee grooves, and actuating spur gears. A hand brake is fitted. It is used for passengers and for light goods in warehouses. Such lifts are made in capacities ranging from 2 to 10 cwt.

An important detail of any suspended lift used for passengers is the provision for safety in case fracture of the ropes should occur. Many patents have been taken out for these.

Waygood's safety gear acts by the pressure of cams on the wood runners which guide the movements of the lifts. In this the ropes are led down from the top corners of the framing to the bottom of the cage, and attached to a sliding plate—a kind of equalising lever—which is maintained in position by the weight of the cage and the tension of the ropes. The cams, four in number, are attached to this plate, two at each end, and connected by shafts passing beneath the cage. Should a rope or ropes break, the cams are drawn inwards simultaneously, and grip the wood runners between which the cage moves. In the improbable event of all four ropes breaking, a fifth rope is fitted. This carries no weight unless all the other ropes fail, in which event the strain comes upon this rope, which, being attached directly to one of the cams, would pull on all four and hold the cage up.

Automatic Lift Gates.—It is now common to fit such gates to "Fool-proof" service lifts, so that none but the authorised attendant at the service floor is able to control the opening and closing of the gates. From this floor the box can be dispatched to any floor desired. But on the opening of the door the apparatus becomes locked, so that the box cannot be moved till the door is closed. The automatic closing of the door is the means whereby the box is returned to the serving floor. There is also a safety gate lock added by the Easton Lift Co. to their car switch, or push button controller, which renders it impossible for the attendant to start or move the lift until all gates are closed and locked. A. Smith & Stevens also make a lock of this character, but in which the *gate must be absolutely locked before* the current is put on.

Electric Drives.—Electric lifts in one system are driven and reversed directly by a reversing motor, which is started, stopped, and reversed with each journey of the cage. No current is consumed when the cage is not working, but the original outlay is greater than with a continually running motor.

In the other system the motor runs continually and is belted to a countershaft, whence other belts drive the lift in opposite directions. Current is wasted while the lift is idle, and the noise of a countershaft would be objectionable in many buildings.

In high-speed electric lifts provision has to be made in the winding of the motor, and the design of controller for rapid acceleration of speed, and a large range of variable speeds without shock.

A compact design of electric lift drive is that in which a motor drives a worm directly, and a worm wheel to a rope drum or sheave.

Ropes.—In the drum drive, a separate set of ropes is used for the suspension of the cage, and of the counterbalance weight, each set being anchored to the drum. The car ropes are being wound on while the balance weight ropes are being unwound, and *vice versa.* The drum is therefore grooved to carry a length of rope equal to the height or travel of the lift. It is preferable, as in cranes, to make the drum with right and left-handed threads from the centre to the ends, to maintain the lift centrally, instead of following the lateral traverse of

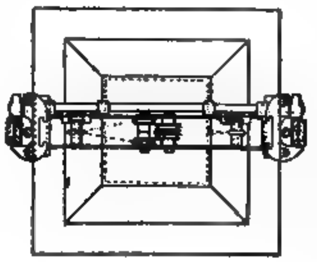
the ropes. Two ropes are used for the lift, and two for the balance weight.

To avoid the lateral traverse of ropes on a drum, and the need for a slack cable required with a drum drive, a sheave drive has been substituted, having vee grooves. The ropes are not attached as to drums, but the car is attached to one end of the ropes, and the balance weight to the other, and the ropes are driven by the friction of the vee grooves. The vee drive was introduced by Messrs Smith & Stevens many years ago for winding engines with steel ropes. The object sought was to obtain greater safety by preventing the over-winding which so often occurs with the drum machine. The safety is due to the slackening of the ropes in the vees when the balance weight or cage reaches the bottom. The question of traverse on the drum was a secondary consideration. It has been stated that this design causes more wear on the ropes than the drum drive does. But on the point of wear and tear of ropes, opinions differ considerably. Messrs Smith & Stevens have employed both vee and drum in winding engines and for lifts for many years, and find that vee wheels do not wear out any more quickly, provided grooves and ropes are suitably made.

In the Easton *cross-over drive* four suspending ropes are used on an eight-grooved sheave, with grooves turned to the radius of the ropes, so avoiding the friction inseparable from vee grooves. The four suspending ropes are first laid over half the circumference down to a four-grooved jockey pulley just below, and having its axis set at a slight angle with that of the main pulleys. Thence the ropes are again led round the second set of grooves on the driving pulley. The ropes are smaller in diameter than when two are used, and it is found that their wear is about equal to that of ropes on drums.

To prevent slackness due to the stretch of some ropes over others, equalising gears are fitted and attached to the balance weight.

In the safety gear shown in Fig. 95, four ropes are employed, and are led under guide wheels in the top cradle bar, two to the right and two to the left. The ends of each pair are attached to the ends of short rocking bars lying transversely in the cradle bars, so that the stretching of either rope will give motion to one of these rocking bars, and each of these, by means of tappets on the cam shaft, throws gripping cams into operation on both sides of the cage.



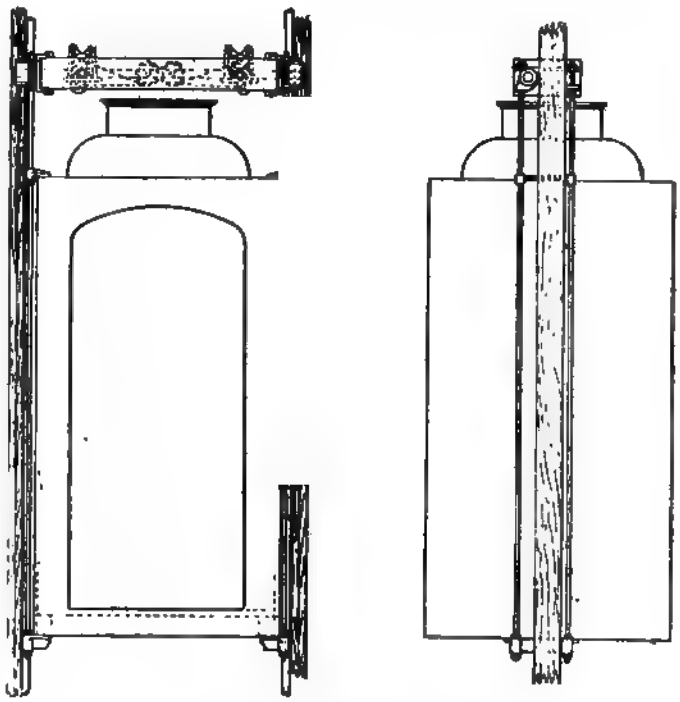


Fig. 95.—Safety Gear. (A. Smith & Stevens.)

Hydraulic and Electric Lifts.—In comparing the relative economies of hydraulic and electric lifts, regard must be had to the circumstances of each case. The choice must often depend on which kind of power is already installed, and on the relative costs of each when an installation has to be made. For low lifts and

heavy loads the hydraulic should generally have the preference, but for contrary conditions the electric scores.

One reason for the economy of the electric over the hydraulic lift is that due to counterbalancing. The car is counterbalanced by a suspended weight, so reducing the maximum load on the motor. If the counterbalance is increased to include the average live load carried in the car, then the motor will only have a light duty to perform. On the other hand, the hydraulic cylinder must be filled at each stroke, regardless of light loads.

Many figures prove that though the first cost of hydraulic lifts is less than that of the electrically-driven ones, yet the expenses of operating them are very materially greater, current costing less than high-pressure water, and much less than water from low-pressure mains. It has not been proved that electric lifts cost more for repairs than hydraulic ones do. But a greater argument in favour of electric lifts is that most large buildings and works now include an electric lighting plant, and this can be extended to include the lifts more cheaply than to lay down an hydraulic plant for them. One man can also better look after an electric plant, than both electric and hydraulic.

Lighthouse.—A tower-like structure, built on a dangerous coast or islet to give warning of danger to vessels.

Lighthouses are built of iron, masonry, or concrete. Iron plates resembling tank plates are bolted together by their flanges, and the joints caulked. Window and door frames are made of gun-metal. Staircases are of spiral form, of cast iron. But such a structure would not be strong enough to withstand the lash of the sea in exposed situations. Here masonry is used, the stones of which are joggled together. Of late years concrete has been largely invading the province of masonry. There are several examples of light framework of cast columns, and wrought-iron braced structures.

The illuminating apparatus has been highly elaborated. The earlier lights were fixed, as are many now, but large numbers are revolving, which enables lights at different spots to be distinguished from each other, and also largely increases the power of the beam. Another method of distinguishing lights is making them occulting; in this system the lens is of the ordinary fixed type, but by a mechanical arrangement the light is periodically covered or extinguished, thus producing an intermittent character of light. The earlier methods of reflection were *catoptric*, denoting metallic reflection. Modern lights are *dioptric*, in which glass is used for reflection and refraction, in which case about 25 per cent. of light is saved; and the *catadioptric*, in which both glass and metal are employed. The term *holophotal* denotes the condensation of an entire sphere of rays from a lamp into a single beam, without wasteful reflection and refraction. The occasion for the numerous designs of lenses and prisms lies in the necessity for condensing the rays that would be dispersed in upward and downward directions, which is accomplished by arrangements of prisms above and below the main lens, which bend those rays downwards and upwards respectively. The spread of the rays is not interfered with in the horizontal direction in a fixed light, but these have to be coerced in a revolving light. The displacement of the parabolic catoptric reflector has been due to the Fresnel dioptric system, which includes lenses, refractors, and prisms. In 1822 Fresnel designed a lens built up of rings, the centres of curvature of which receded from the axis according to their distance from the centre. This device had the effect of eliminating the spherical aberration of a solid lens. Fresnel's cylindrical refractor was a glass hoop for rendering the rays parallel in a vertical plane. Fresnel's reflecting prisms were designed for reflecting rays horizontally. His refracting prisms refract the rays which fall on them in one plane. The foregoing in various combinations have been embodied in most modern illuminating apparatus. These, with improvements effected in the lamps themselves, by Fresnel and others, have produced designs suitable for all conditions.

Oils have been, and are used largely for lamps. The wicks are arranged in concentric circles. A single large lamp has been substituted for several separate lamps. Electric arc lamps have entered into rivalry with

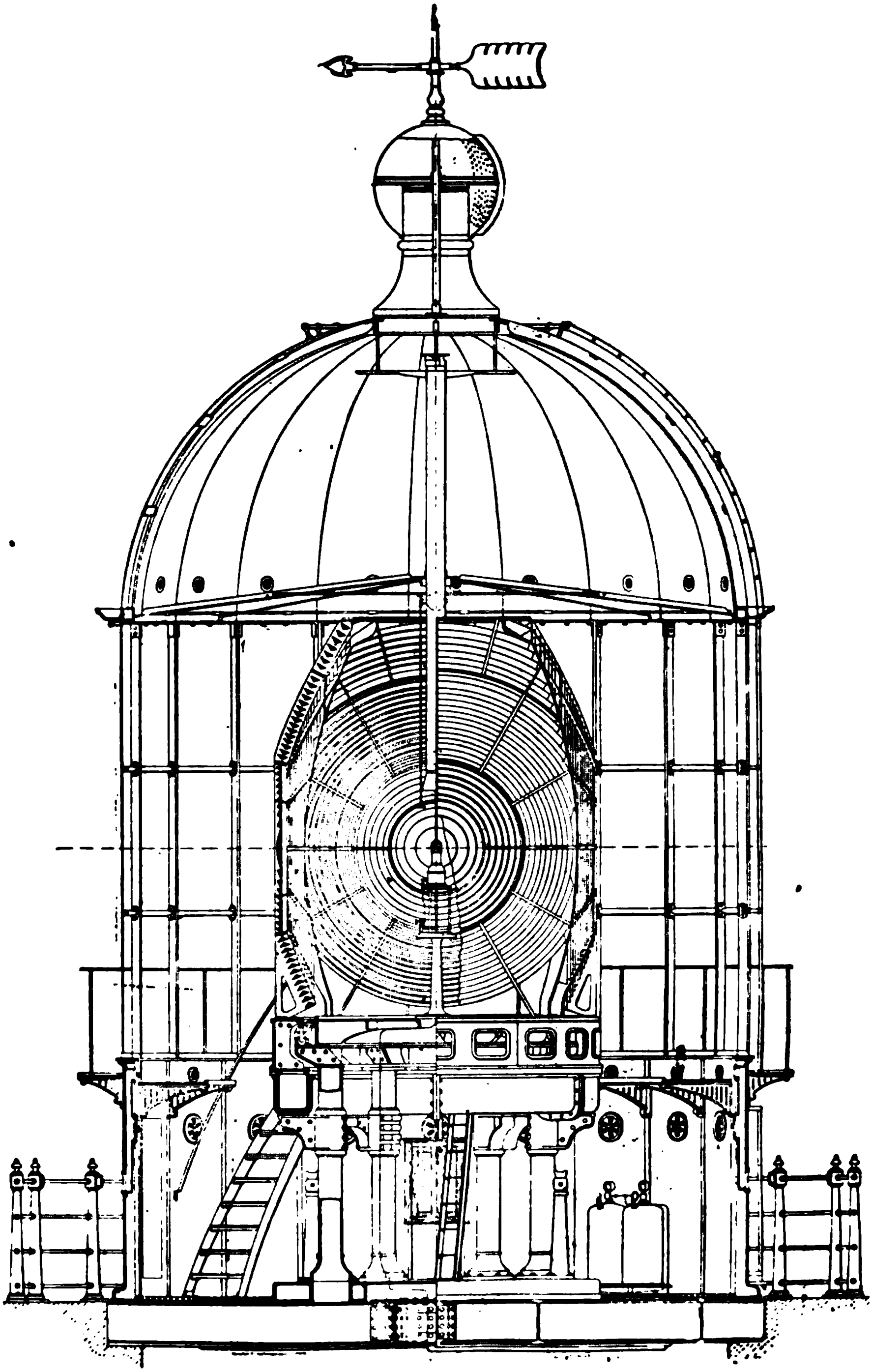


Fig. 96.—Optical Apparatus and Lantern of Lighthouse.

these. But the latest type of burner, which has now come into general use, is one employing petroleum vapour, with an incandescent mantle. Descriptions of optical lighting arrangements, which would occupy several pages, must be sought in works devoted to the subject. The remarks to follow bear on the conditions which have to be fulfilled by lighthouses.

The height of the focal plane of a lens differs with the order of lens, as the smaller orders of lights have a less optical range than the larger, and therefore need not be placed at such a great elevation to get the geographical range required. The mean heights above the sea of the focal plane for first, second, and

Fig. 97.—Plan of Optical Apparatus.

third order lights are about 210 ft., 180 ft., and 145 ft. respectively, and the distance of the horizon is situated at 16·8, 15·5, and 14·0 nautical miles respectively. The height of the focal plane of a lens varies much with locality.

The optical elements of the lens are so set as to direct the best portion of the light from the source to the horizon, the natural divergence due to the size of the source of light covering the sea between the lighthouse and the horizon. In certain special cases, such as a lighthouse placed at a great elevation, or one with a very small source of light, special arrangements for covering the near sea are necessary, and this is done by focussing the different elements on to points at different distances.

The term *group flashing* relates to the system devised by Dr Hopkinson for revolving lights. By this device, though the apparatus is rotated at a constant speed, flashes of unequal duration, and with unequal intervals, are readily obtained. It is done by arranging the panels of prisms unsymmetrically, their axes not being central in relation to their width, but alternately closer together and farther apart. Thus the required angles in the plane of the azimuth are imparted to the flashes, and to their intervals.

The weight of the illuminating apparatus is carried round on live rollers, or in later designs in a bath of mercury. Thus at Lundy, the apparatus, weighing 3½ tons, is carried and floated on 7½ cwt. of mercury. A touch of the finger suffices to set it in rotation, which will continue through several revolutions.

The lantern, optical apparatus, burners, &c., shown in Figs. 96 and 97, were designed and constructed by Chance Brothers & Co., Ltd., at their works near Birmingham. The lantern is circular in plan, 17 ft. 1½ in. diameter internally, and consists of a cast-iron murette or base with ventilating panels 7 ft. in height supporting the vertical steel frames carrying the glazing and dome. The glazed portion is 12 ft. 5 in. in height, the dome being of copper carried on steel rafters and surmounted by a ball ventilator and wind vane. The height from the base of the lantern to the top of the vane is 37 ft. Galleries are provided externally and internally at the level of the upper part of the lantern murette, and there is an external gallery with balustrade at the lantern floor level. The weight of the lantern complete with its floor is about 28 tons.

The optical apparatus is of the largest size used in any lighthouse service of the type known as "Hyper-radial" of 1,330 mm. focal distance. The revolving optic consists of four panels, each of 90° horizontal angle, with a vertical angle of 121°. The lens or refracting segments in each panel consist of a bull's eye and nine annular rings, the angle being 57°. Twenty-two catadioptric or reflecting prisms

are placed above the lens elements, and thirteen below. The glass elements are mounted in gun-metal frames, the weight of which latter is about 2 tons 2 cwt., the optical glass weighing about 2 tons. The optic is mounted on a cast-iron table carried on an annular cast-iron float immersed in a mercury bath of similar section in which it rotates. The total weight floated is about 7 tons. For floating this mass 950 lb. of mercury are required in the bath. The bath is carried on six cast-iron columns forming a pedestal.

The apparatus is rotated by a clock-work machine placed alongside the pedestal. The clock weight is 8 cwt. and the fall 14 ft. 6 in. per hour. The weight descends through a weight tube constructed in the centre of the tower.

The optic makes one complete revolution in thirty seconds, producing a flash of 0·3 of a second duration every seven and a half seconds. The weight of the pedestal supporting the optic is about 10¾ tons. The illuminating apparatus consists of a Chance incandescent petroleum vapour burner with mantle of 85 mm. diameter. The power of the beam emitted from the optic is upwards of 1,100,000 standard candles.

Light Railways.—Railways of all gauges, but generally narrower than standard, in which the weight of the permanent way and of the rolling stock is minimised. Included within this general definition, a light railway might mean anything from the narrow gauge trucks about a works to the feeders of the main line railways in remote districts, and to ordinary tramlines.

The arguments in favour of light railways are chiefly the low first cost, by which they can be made remunerative in districts which would be unable to support the regular system. A few years ago greater results were anticipated from these railways in the transit of agricultural produce than have been realised in fact. It was believed that railways of narrow gauge could be laid down alongside the country roads, and collect the produce from farmers and fruit growers and so serve as feeders to the main lines. That result has not been achieved, but in the carrying of passengers, light railways have proved of considerable value as feeders to the main lines, for the most part, however, as lines of standard gauge with motor or steam coaches. The laying down of permanent way of narrow gauge alongside the high roads is not now likely to be realised in face of the growth of motor vehicles which do not require rails.

In another direction, however, light railways are used to an increasing extent, as means of transit about big factories, yards, mines, quarries, and about large public works and contracts. The system has given occasion to the development of a vast amount of plant, numerous sections and weights of rails, different types of sleepers, and methods of laying them, of turntables, switches, and crossings, of locomotives and wagons—now a highly specialised department of mechanical engineering. Electricity has also largely entered into rivalry with steam as a means of propulsion.

Examples of pressed steel sleepers are shown in Fig. 98, Plate VI. They are formed with ribs or corrugations for the purpose of stiffening, the central groove being continued to the ends, so that water drains right off. The ends are turned down to prevent lateral movement, and to stop the ballast from washing out. The sleepers are deeper at the centre, to impart stiffness, and to enable them to take a proper bearing on the ballast underneath the rails. The latter are held with chairs punched from the solid sleeper, one key being used in each chair opening. Weights of sleepers range from 8 lb. to 15 lb. per yard. They are coated with Dr Angus Smith's anti-corrosive composition to prevent rusting.

Fig. 99, Plate VI., is a typical example of a saddle-tank locomotive specially suitable for contractors' work. In the smallest size of this engine the cylinders are 4 in. bore, and the engine will haul a load of 41 tons on the level. The gauge is 18 in. and the weight of the locomotive 2¾ tons. Others with cylinders of 5, 6, 7, and 8-in. bore are made, on the same design, having capacities ranging up to loads of 188 tons on the level.

The usual pattern of end tipping wagon is that represented in Fig. 100, Plate VI. The carrying brackets for the basket trunnions are of pressed steel, riveted to the frame, so that

there is no risk of their spreading when the wagons bump. The side tipping wagons are constructed on a similar plan, the only difference being that of the axis of the trunnions.

A type of wagon made with open sides for carrying hot coke, is given in Fig. 101, Plate VI. The openings allow the escape of water which is used in cooling off the coke. This is a side tipping wagon.

Lightning Arresters.—Wherever overhead lines are used for electric transmission, the lines themselves, receiving lightning discharges, or being within the influence of the violent electrical surges produced

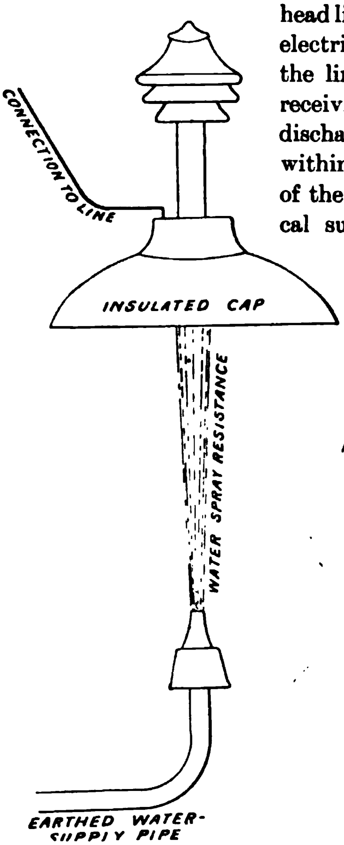


Fig. 102.—Lightning Arrester.

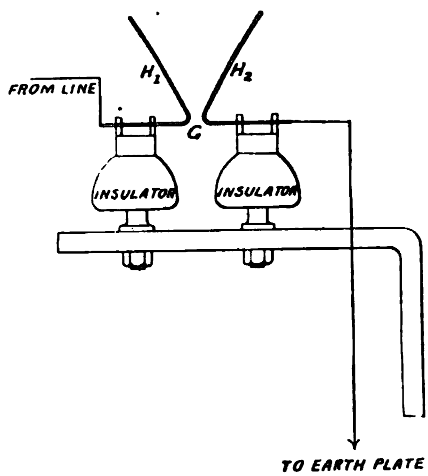


Fig. 103.—Lightning Arrester.

when discharge takes place between clouds in the district, provide a path by which the atmospheric electricity at enormous potential can pass through the apparatus connected to them. As the discharge must reach the earth somehow, it would do so by jumping the switchboard connections, piercing the insulation of the dynamos, or in an earthed system by passing through the magnet coils. Whichever course it took, considerable damage would result.

Lightning arresters are therefore fitted at both ends of the outside lines, and have the effect of diverting the discharge to earth by affording it an easier and shorter path than the insulation resistance of the main circuit.

On lines where large power and high pressures are used, the arrester is sometimes formed as in Fig. 102.

An inverted metal cap is connected to the line and a very fine vertical water jet playing upon it forms a high resistance path to earth. Thus the line is permanently connected to earth, but the resistance of the water being so very high an exceedingly small current is wasted, whilst on the other hand perfect protection of the lines and machinery from damage by lightning discharges is by this method assured.

Gap arresters are commonly used as being a simple and effective device. Fig. 103 shows the arrangement, and the action is as follows:—The line is connected to one of the horns (H_1) and the gap between this and H_2 is adjustable to suit the voltage of the line, and so prevent a continuous connection of the line to earth. The lightning discharge takes place at the point G where the horns are close together, an arc is formed, and ascends, due to the upward current of heated air in contact with it, until it becomes so long that (the lightning having of course passed instantaneously to earth) the voltage of the generators feeding the line can no longer maintain it and it therefore breaks. On a three-phase earthed system, whilst this arc lasts, one phase winding of the generator is of course short-circuited, but with 10,000 volts its duration is only one five-hundredth of a second, so that no harm is done in such a short time.

Lightning Conductors.—Metal rods attached to the outside of buildings terminating in a point higher than the building, and running down into the ground to a buried earth

plate. The theory is that discharges of atmospheric electricity in the vicinity will select the metal rods as being the path of least resistance, and thus be conducted harmlessly to earth. Whilst the eccentricities of lightning discharges have shown that lightning rods are not an absolute protection, there is evidence that the system is often effective, and they are usually fitted to all high buildings, chimneys, &c. The subject of atmospheric electricity is somewhat obscure, but is now receiving greater attention, which, however, has so far only affected the theoretically better disposition of the conductors, without producing any alternative system of protection.

Lignum-Vitæ, or **Guaiacum-Wood.**—A tree of the natural order *Zygophyllaceæ*, the supplies of which come from tropical America and the West Indies. It is extremely hard and heavy, a cubic foot weighing when dry from 72 to 83 lb. The grain is very tortuous, the surface greasy, the colour dark brown. Its chief value is for the sub-aqueous bearings of turbines, propeller bushes, and for ship's pulley blocks.

Lime.—Lime, or calcium monoxide, CaO, sp. gr. 3·08, is prepared by heating chalk or limestone, $CaCO_3$, with coal in kilns. Carbon dioxide, CO_2, is driven off ($CaCO_3 = CaO + CO_2$) and the quicklime remains. On adding water to lime, great heat is produced, the lumps crumble to a fine powder and the resulting compound, $Ca(OH)_2$, is called slaked lime. Slaked lime is slightly soluble, 1 part in 730 of water, the solution being known as lime-water, and used chiefly as a test for carbon dioxide; the presence of this gas is denoted by turpidity of the solution due to the insoluble carbonate of lime formed. The readiness with which the hydrate absorbs carbonic acid from the air, thus producing setting or hardening, explains the use of lime in mortars and cements. *See* **Cement.**

Quicklime exposed to the air gradually absorbs vapour and becomes "air slaked." It is therefore necessary to preserve it by grinding to a powder and packing in air-tight barrels.

The carbonate and sulphate of lime are present as incrustations in boiler tubes, being deposited from impure feed water. For the use of limestone in the production of slags, *see* **Iron.**

Limit Gauge.—The work of the modern machine shop requires a high degree of accuracy. But such a condition is not absolute, but relative only. Absolute accuracy is quite unattainable, while the practice of economy must never be carried so far as to jeopardise that degree or amount of mechanical truth which should be embodied in any given class of manufactured article.

Absolute accuracy, using the term in its mathematical bearings, is not only unattainable, but it is not essential in the practice of engineering. Mechanics, however, approach very near to it in their finest measuring machines, which indicate easily the $\frac{1}{1000000}$th part of an inch, and measure exactly and precisely the $\frac{1}{10000}$th part of an inch. The latter is, in fact, a dimension that is frequently required in high-class precision tools. But in by far the larger volume of general work done, the limits of dimensions necessary, or desirable range between the $\frac{1}{1000}$th and $\frac{1}{2000}$th part of an inch. For comparatively rough mechanisms the limits are as low as from $\frac{1}{100}$th to, say, $\frac{1}{500}$th part of an inch.

In all interchangeable work the question of limit gauging comes in. The necessity lies in the wear of the cutting tools, and in slight inaccuracies inseparable from mechanical operations. The limit is fixed rigidly by different gauges, an article going in one and not in another of a slightly different size. The precise limit allowed depends on the nature of the work, and it will therefore vary rather widely in different parts of the same machine. But it is always a precise amount, measured in so many hundredths or thousandths of an inch. The standard gauges, made to exact sizes as nearly as possible, only show exact dimensions. The finest of these can only be slid within one another by the application of a film of oil. If they were engaged forcibly without the oil, and left for a few minutes, they could not be separated without force, and abrasion of the surfaces in contact. The ordinary shop working gauges can be used without oil, though it is the practice to keep them lubricated slightly. But neither of these gives any positive measurement for either driving, or running fits.

The ring, or hole gauge is the starting point,

made to standard sizes, but though the ring gauge will go over a shaft smaller than the bearing in which it is to run, or the boss into which it is to be driven, the gauge will not show *how much smaller* the shaft is than standard, but the workman must make it a matter for guessing, or trying with calipers.

The terms "tolerance" and "allowance" are frequently used in reference to systems of obtaining different classes of fit and interchangeable work. These two terms represent entirely different quantities. *Tolerance* is to provide for reasonable error in workmanship compatible with tools and methods used in production. *Allowance* is the necessary difference in the size of the pieces that have to go together to obtain the quality of fit wanted. The term "limits" is generally used to convey the meaning of both tolerance and allowance, that is to say they express the system of tolerances and allowances as a whole. To take an example: the limits for a 6-in. running fit may be, approximately, as follows:—the hole would not be larger than 6·002 in., and not smaller than 5·998 in., the difference between these two sizes (·004 in.) representing the *tolerance* for the *hole*. The size of the shaft would not be larger than 5·996 in., and not smaller than 5·993 in.; the difference between these (·003 in.) represents the *tolerance* for the *shaft*. Now, the *allowance* is the difference between the mean size of the hole and the mean size of the shaft, in this case ·0055 in., which is, approximately, the amount necessary for freedom in an easy running fit of 6 in. diameter.

But when the question of limits is gone into with a view to the construction of standard difference gauges, the *range of limits* desirable becomes rather a deterrent. The old terms, "full," "bare," "tight," "slack," "driving," "running," do not stand for anything precise. Hence a good deal has been written, formulæ proposed, and diagrams prepared which rather tend to confuse the issues to the man in the shops.

Since it is not economically possible to make these gauges for each separate piece of work which has to be done, and since when work is largely repetitive it does pay to make special gauges for the measurement of a large number of similar pieces, much variety exists in the types in which they are made.

The Newall Engineering Co., Ltd., have greatly simplified the work of limit gauging. They standardised a complete series of limits for different classes of fit and grades of workmanship. Fits are classified as follows:—

Force Fits, which require a screw or hydraulic press to force them together. *Driving Fits*, which require the use of a hammer to drive a spindle into its hole. *Push Fits*, in which the spindle can be thrust into its hole by hand. *Running Fits*, which include all classes of running work. As these demand various degrees of looseness, Messrs Newall subdivide them into three groups, X, Y, Z. The gauges made for these range from ½ in. to 6 in. nominal diameters.

Limit gauges are of the plug and ring, and the snap types. The first are complete cylinders, the second bear only on narrow edges. The "go in" or "go" when applied to the hole is the standard; "not go in," or "not go" is the limit gauge. In order to avoid risk of error, the end which goes in is made longer than the not go, so that the workman knows by sight which to use.

For external limit gauges the horse-shoe, or crescent form of snap is often preferred, especially for the larger dimensions, plug gauges being retained for the hole of standard size. To prevent alteration in size by the heat of the hand, vulcanite handles are often fitted to the larger gauges. The methods of construction resemble those of **Caliper Gauges**.

The Newall Engineering Co., Ltd., make external limit gauges of crescent form which combine the "go" and "not go" in the same gauge. In one set the points are fixed, in the other they are adjustable. A set of the fixed point gauges is recommended for the diameters and class of fit most commonly used in a given shop. Then a set of adjustable limit gauges for intermediate diameters and classes of fits not commonly used. The setting is done by hardened reference bars ground to two dimensions, namely the high and low limits for the various classes of fits. There is another size of setting bar, to standard size only. Provision is made for setting the adjustable calipers from

a standard plug. A graduated dial is used and an index plate. After the anvil screws are set to standard, the dial is attached to one of them, and its zero brought to the + or − of an index, and the screw which carries the dial is moved to the limit desired and locked. Then the dial and index plates are transposed, and the second screw is set and locked in the same way.

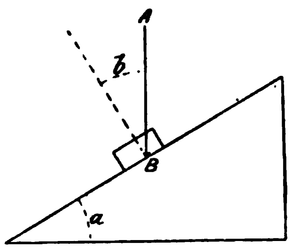


Fig. 104.—Limiting Angle of Resistance.

Limiting Angle of Resistance.—A term sometimes used to denote the angle of friction, or the angle made by a plane with the horizontal when a body barely begins to slide. At such a moment, the angle b, Fig. 104 (made by the line of force A B and a line perpendicular to the surface of the plane), is equal to a, the limiting angle of resistance.

Limiting Sizes of Gear Wheels.—The full importance of this subject has only arisen since the system of working gears interchangeably has become an essential feature in shop practice. The matter may be put thus:—That for either of the systems of gear teeth in use there is a basis on which the system is built, which sets a limit to the smallest wheel that can be made to engage correctly with any wheel in the series. There is no limit in the other direction up to a rack. What happens when pinions smaller than the basis are made is, that the flanks become undercut and weakened. This does not apply with so much force to bevel wheels, because they can be made of special design with special cutters, but it affects spur and worm wheels. The exigencies of engineering practice demand standard gears, and also exceptionally small gears at times when the limitations set up by standardization have to be circumvented. These difficulties can be surmounted properly only in involutes. In cycloidal teeth, with pitch lines rigidly fixed, the only course is to accept the undercutting, with consequent weakening of the teeth. But in involutes, the positions of the pitch lines can be altered, and the undercutting thus avoided.

Limits.—This signifies the precise amount of variation from stated absolute dimensions, which is guaranteed by manufacturers. Thus, a dimension may be stated to be 2 in., and then the work guaranteed not to vary from 2 in. by more than $\frac{1}{100}$th, or $\frac{1}{1000}$th, or $\frac{1}{5000}$th of an inch, more or less. Or bars of steel may be stated as of 28 tons tensile strength, and guaranteed not to exceed that strength by more than 2 tons.

The limits of accuracy demanded to-day are vastly more close than they were a few years since. But this does not imply that there was not such accurate work done as at present, which would be absurd. What is meant is, that the general standard of accuracy has been raised, and that new methods of working and of measurement have come into use, by the aid of which more precise results are obtained at an expenditure of less labour and individual skill in handicraft. Formerly a workman could only judge of exact measurements by the sense of touch, full or bare, tight or slack, hard or easy. Now he can measure corresponding differences in one or two thousandths of an inch. *See* **Limit Gauge**. Further, nice adjustments were formerly a matter of filing, or emery cloth, or powder, or scraping. As a rule they can be performed now by means of grinding processes, sometimes by cutting with mills. It is chiefly, however, the grinding machines, and the micrometer and plug and ring gauges of various types that have made possible precision in the finest engineer's work.

Lincoln Milling Machine.—A horizontal spindle machine of moderate capacity which has the merit of great rigidity, and which is suited for "manufacturing" purposes. An example is shown by Fig. 105 on Plate VII. The table is supported on a bed, and traversed under the cutter, which has a range of vertical adjustment. The arbor has its bearings movable on the faces of uprights; or, in the smaller machines, within them, as slotted housings. Independent elevating screws are used in the small machines, operating directly, or through mitre gears. The arbor bearings are often

moved simultaneously, by a set of gear in the fast headstock, by connecting this and the tailstock bearing with a very rigid bar. The uprights are often divided into inches, and thousands, or sixty-fourths of the inch. Counterbalance weights are fitted to most machines to the spindle bearings and slides. The tailstock is generally provided with a horizontal movement along the bed, to suit arbors of different lengths. The headstock is a fixture bolted to, or in some small machines cast with the bed. The bed may be a cabinet base, as in the larger machines, or resemble a lathe bed carried on legs in the smaller. In many cases, but not invariably, the table has a cross traverse motion of a few inches to permit of accommodating work to the cutters. Driving is done from stepped belt cones on the head through gears. Feeds are by stepped cones. A worm and worm wheel drive the table through gears. A trip device is fitted by which the worm is dropped out of engagement with its wheel at the end of a cut.

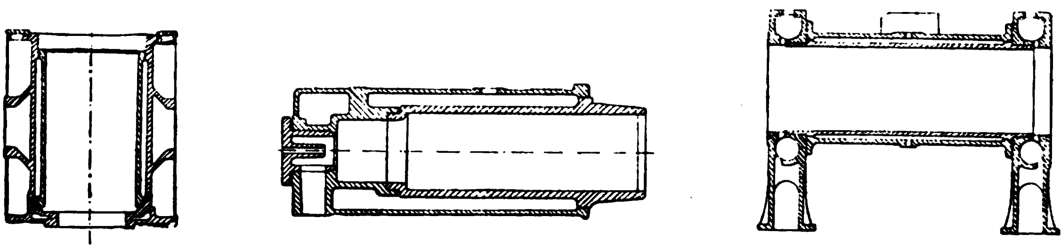
Line.—A line is length without breadth. A straight line is the shortest distance between its extreme points.

Linear Velocity.—*See* **Velocity.**

Liners.—The term is applied to bushes for pumps or engine cylinders, and to sheaths or casings for air pump and other rods. The object of the first is to provide a better, or more durable wearing surface of a more expensive material to a cheaper body, or to a body which could not be so readily cast as the liner; that of the second is to provide a rustless covering to a stronger and more rigid rod that would corrode if unsheathed.

Liners for Cylinders.—These are necessary to provide a good and durable wearing surface for the piston. The metal in these is closer, harder, and stronger than that in the cylinders, and consequently more expensive. But it is also economical, because it would be very difficult to cast a cored cylinder from metal hard enough for liners. The risk of a waster would be serious, while if a cylinder body has to be lined, a few blow holes in the walls that come next the space between the cylinder and liner are of less importance.

Cylinder liners are made generally in cast iron, but sometimes of cast steel, or of fluid compressed steel. They are fitted in various ways. But generally they make contact with the cylinder bore at both ends, leaving a steam space of about 1 inch in the space enclosed between the end fitting. One end may be flanged or not. A shrink, or force fit makes steam-tight joints. A slight expansion of the cylinder by the application of warmth permits of the insertion of the liner. Faces are fitted of hard metal to the valve faces of steam chests for durability, being attached with cheese head screws, locked by drifting the heads into nicks recessed in the holes arbored for the heads. Figs. 106 to 108 illustrate liners for a vertical cylinder, for a gas engine cylinder, and for a Corliss cylinder respectively.



Figs. 106, 107, 108.—Liners.

Pump Liners.—Liners of brass and gunmetal are fitted in the cast-iron bodies of pump barrels to avoid corrosion and reduce friction. They fit at the ends, and at intermediate portions by narrow bands, to correspond with similar bands bored in the pump body. They may be driven in with wood blocking, or be drawn in by pressure, obtained by turning a nut on a long bolt, the head of which bears against a bridge piece or disc outside the other end of the cylinder. But the best plan is to force the liner in with a hydraulic press. The boring may be done before or subsequently to the pulling in.

Rod Sheathings.—Rods of steel are sheathed with brass liners to secure the strength of the steel with the freedom from corrosion of the brass. They are either shrunk on, or cast on. If shrunk they are bored, and enlarged sufficiently by warmth to slip over the turned rod, to which they hold tightly when cold. When sheaths are cast around a rod the difficulty lies in the shrinkage of the brass. It is therefore necessary to heat the rod to a low red, so that it shall shrink along with the cooling brass. It should also be rough-turned to afford a better hold to the metal. The mould is made in dried sand, and means taken to place it concentric with the shaft. Risers should be used freely.

Line Shafting.—The main shafting, or first motion shafting, whence machines are driven, generally through a countershaft. Its drive is constant, but the fast and loose pulleys are put on the countershaft.

Lining Out, or **Lining Off**, or **Marking Out.**—Setting out, or drawing centres and lines on castings and forgings as guides to the turner, machinist, and fitter, in tooling and finishing their surfaces. It is an alternative to work done by templets, and in jigs, being adopted for single pieces of work, or for small numbers only; the templets and jigs being used when large numbers are in question.

Before any lining out can be done, a level base is necessary. Sometimes the bed of a lathe, or a machine table is utilised, but for regular work a cast-iron table is employed. This is a rigid table from $1\frac{1}{2}$ in. to 2 in. thick, ribbed round the lower edges, planed on top and around the edges, and carried on trestles or blocking. Its dimensions are made to suit the average run of work in a shop, and may be from 6 ft. to 12 ft. long, by from 3 ft. to 4 ft. wide. On this table work is laid directly, or packed up on suitable blocks (*see* **Vee Blocks**), or with wedges, &c. If planed faces are not available to lay on the table face, the packings afford the means by which faces or centres are levelled up parallel with the table. The rule is not used in this levelling except for rough adjustments, but the surface gauge or scribing block is employed for all horizontal centre lines, and to check the truth of horizontal surfaces, whether upper or lower. Vertical centre lines are obtained by means of a common trying, or set square. In some cases work is bolted to the vertical face of an angle plate for lining out. Light articles are moved about by the hands, but for heavy ones there is usually a crane provided, which may be of any convenient type, a swinging jib crane, or a suspended hoist of any suitable form.

In all lined-out work except the simplest there are several related parts, as faces, centres, and so on; and the more numerous these are, and the smaller the allowances left for tooling, the more care has to be exercised in lining off. A tentative marking out has often to be made, to be subsequently corrected. Generally there is some one portion required more accurate than another, as for example a cylinder bore, or the distance of a foot from a centre, which would be of more importance than, say, the thickness of a flange. The latter must then be accommodated to the former. Difficulties arise in cast and forged work in consequence of the inequalities of the allowances for tooling, which are often in excess in some parts, and skimped in others. Or it may be necessary to throw centres out, with resulting excess for tooling in one part and reduction in others, in order to average sufficient allowances in other parts.

When there are several holes for bearings, cored, or solid, these have to be set out at their correct centres, and generally in relation also to feet or brackets. Always the more important relations must be secured, and the less important accommodated thereto. In some classes of work, not machine-moulded, and containing numerous cores, the task is not easy; so too in many large forgings of awkward shapes, allowances must generally be in excess. Machine-moulded castings, and drop forgings may have minimum allowances, though these are generally either lined out from templets, or tooled in jigs.

Lines are scribed on a chalked or whitened surface. Pencil lines are useless, because easily effaced. It is usual also to centre-pop the course of the lines, as even scribed lines become faint by much handling, and from grease and oil. Another device is the *witness line*, which is struck parallel with another, or concentric with a circle, to remain after the actual working line

has been tooled by. This also is centre-popped.

Link.—Gunter's chain, used in land surveying, is 4 poles or 22 yards in length; the chain is composed of 100 links, and hence a link measures 7·92 inches. The middle link in the chain is marked by an attached circular brass tag, and every tenth link on either side of the middle one is also marked with a smaller tag with one, two, three, or four teeth showing whether it is the tenth, twentieth, thirtieth, or fortieth link from the end.

See also **Closed Chains, Link Motions.**

Link Belting.—Leather belting built up of numerous short links with rounded ends, Fig. 109, A, and riveted together side by side in alternate series to form a wide belt, very flexible in the longitudinal direction, capable of hugging the smallest pulleys closely. It has therefore advantages over the solid belt, chiefly in preventing cushioning of air, which lessens the grip of solid belts.

To increase the value of this belting it is designed in two forms, besides the ordinary belts of parallel thickness. One is a *flexible centre* belt, arched on one or both sides, B, the other a *thick-sided* belt, C. The first-named is an extension of the principle of flexibility embodied in the link design. Though the belt is flexible longitudinally, it is but slightly so in the transverse direction, in consequence of the rigidity of the rivets. The flexible centre belt, B, is made with a centre connection formed of two rows of links united with rivets, that permit of sufficient flexibility to enable the belt to accommodate itself approximately to the curvature of pulleys. This principle is further improved on by arching the belting, that is, imparting a curvature in section to the belting, making the links of increasing width from the centre to the outer ones, so that the belt lies absolutely closely round the pulley.

In the thick-sided link belting, C, the cross section increases from one edge to the other, to enable the belt to lie closely to cone pulleys, and in quarter twist driving, so giving an equal bearing all over the belt width. The two designs are combined in the double arched and flexible centre link belt, to enable pulleys on shafts at various angles with the direction of guide pulleys to be driven with close contact of the belts on all alike. It is claimed that link belting with flexible centre, and arched, will transmit from 20 to 30 per cent. more power than a flat belt. A compound belt, D, is flexible, and arched, and carries a second belt of double orange tan leather independently on the top of the link belt. Messrs Tullis & Son say this returns a gain of 100 per cent. of HP.

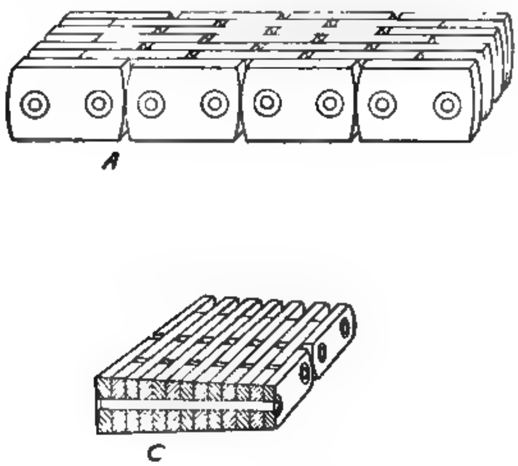


Fig. 109.—Link Belting.

Link Grinding Machines.—These are now represented by several different types, horizontal and vertical, with different methods

of reciprocating the links, or traversing the grinding wheels, and in small and massive designs to suit locomotive and marine work. Generally provisions for hole and link grinding are combined.

The earliest machines for lapping holes and links were designed by Messrs Beyer, Peacock, & Co., Ltd. The essential features of these lie in the spindles, Fig. 110, which are of planet type. An outer sleeve B, carried vertically in bearings A in the framework of the machine, encloses a hollow spindle C, which revolves with B under the coercion of a long key *a*. It is also capable of sliding vertically. This spindle C is bored eccentrically to receive a second hollow spindle D, also bored eccentrically to receive the solid grinding spindle. D revolves with C. It is adjusted eccentrically by the hand-wheel F. It thus carries round the grinding spindle with a definite eccentric movement, while the latter is rotated within it at a high speed by the belt pulley G. The sleeve is rotated by the worm and wheel H and J. J encircles and is keyed to the outer sleeve B, and drives the inner sleeve through the key *a*. The crank in conjunction with the lever K imparts the vertical feed. The maximum stroke is 10 in. This spindle is embodied in machines of various designs and dimensions.

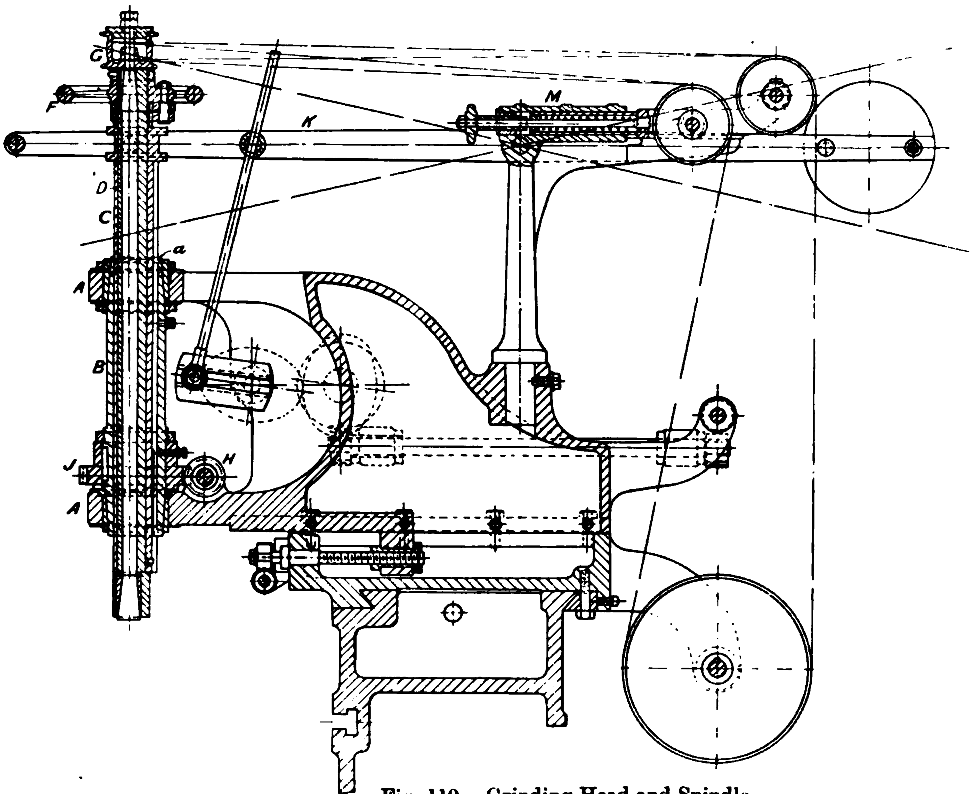


Fig. 110.—Grinding Head and Spindle.

Machines in which these spindles are embodied are shown in Figs. 111 to 113, Plate VII. Fig. 111 is the firm's "E" type. It is designed specially for truing holes in case-hardened motion work, and for grinding either straight or radial expansion links, and blocks; the arrangement for holding the latter is seen in the photo, comprising a radius bar, and a variable self-acting cross traverse by levers. The table is provided with a water trough. A pump provides lubrication. The machine will lap out holes from $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. in diameter, by 4 in. deep; or from $1\frac{1}{4}$ in. to 3 in. in

diameter, by 6½ in. deep; or from 3 in. to 5 in. diameter, by 8 in. deep. The traverse of the spindle along the bed is 4 ft. 9 in. The greatest radius for link grinding is 5 ft. 9 in.

Fig. 114.—Link Grinding Machine. (Longitudinal Section.)

head is carried on a long slide, adjustable lengthwise and crosswise by screws and hand-wheels. The bracket, which is shown supporting the lower end of the grinding spindle, is only used when large links are being ground. It is removed when lapping is being done.

A link grinder by Friedrich Schmaltz embodies the sun and planet motion illustrated in **Hole Grinding Machines**, Vol. V., page 195,

Fig. 105.—Lincoln Milling Machine.
(Pratt & Whitney Co.)

Fig. 111.—Link Grinding Machine.
(Beyer, Peacock, & Co., Ltd.)

Fig. 112.—Link Grinding Machine.

Fig. 113.—Link Grinding Machine for Marine and Heavy Work.

(Beyer, Peacock, & Co., Ltd.)

To face page 104.

Figs. 177-179, with some modifications. The link lies on a horizontal table, which is reciprocated along a bed, with a radial movement derived from a fulcrum block in which the end of a radius bar pivots. The reversals of the slide are self-acting by stops.

Figs. 114, 115 illustrate a link grinder by Hulse & Co., Ltd. The bed A has a projecting cantilever arm B, on which the radius of the link is regulated, and a headstock C which carries the mechanism of the grinding spindle, and that for reciprocating the link. The link is seen at D, carried on a fixture E, which is bolted to the table F, which has compound motions, the motions being derived from the spindle a, and the arrangements on the arm B. A spur gear b on the spindle a drives the gear c on the spindle e, and the latter actuates an adjustable lever G, whence the lever H imparts a traverse motion to the table slide J.

The link pivots about the centre of the block K, which is adjustable along the arm B as far as K′; or, on this machine, from a radius of 6 ft. at K, to 2 ft. at K′. The radius bar L is a tube bolted to the table slide F, which has a horizontal reciprocating movement ranging from 9 in. to 18 in. The fulcrum block K is adjusted along this tube by means of the screw M, to which the lower portion of K forms a nut. The screw is operated by the hand-wheel N and mitre wheels.

The grinding spindle f is rotated by the bevelled friction discs O, from the belt pulley P. It is supported in bearings above and below the wheel f, and is counterbalanced. The vertical reciprocating motion is imparted by the lever

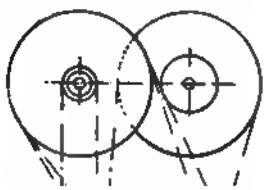


Fig. 116.—Link Grinding Machine.

Q, derived from the cam R. This is operated from the belt pulley S which drives the worm T, and the gears U and V; V being on the cam shaft *e*.

On the Continent, preference is given to the vertical types of machines, of which there are several designs. One, by the firm Le Progrès Industriel, is illustrated in Fig. 116. In this, the machine base A carries a vertical column B on which radius rods C C are pivoted, and on which they are adjustable for height and radius with both coarse and fine movements. The link is carried by loops in the lower ends of these, and is oscillated by means of a feed screw D actuating a sliding block E, and a connecting rod F, one end of which is attached to the block, the other to the radius rod C, which lies nearest it. The to-and-fro motion is derived from open and crossed belts from pulleys on the countershaft to pulleys at the end of a clutch box G, driving and reversing the feed screw D. The grinding wheel spindle H, which has its bearings through the base of the upright, is traversed by a slotted disc and lever J. The table details may be noticed.

Messrs Mayer & Schmidt make a vertical link grinder in which the planet spindle shown in Vol. V., page 196, is embodied. The head is traversed bodily for link grinding by means of a slotted disc and levers. The link is carried on the upper end of a long oscillating arm, the lower end of which goes down into a pit. It is traversed by a slide on the vertical face of a knee on the base of the machine. The radius of oscillation is adjustable by means of screws.

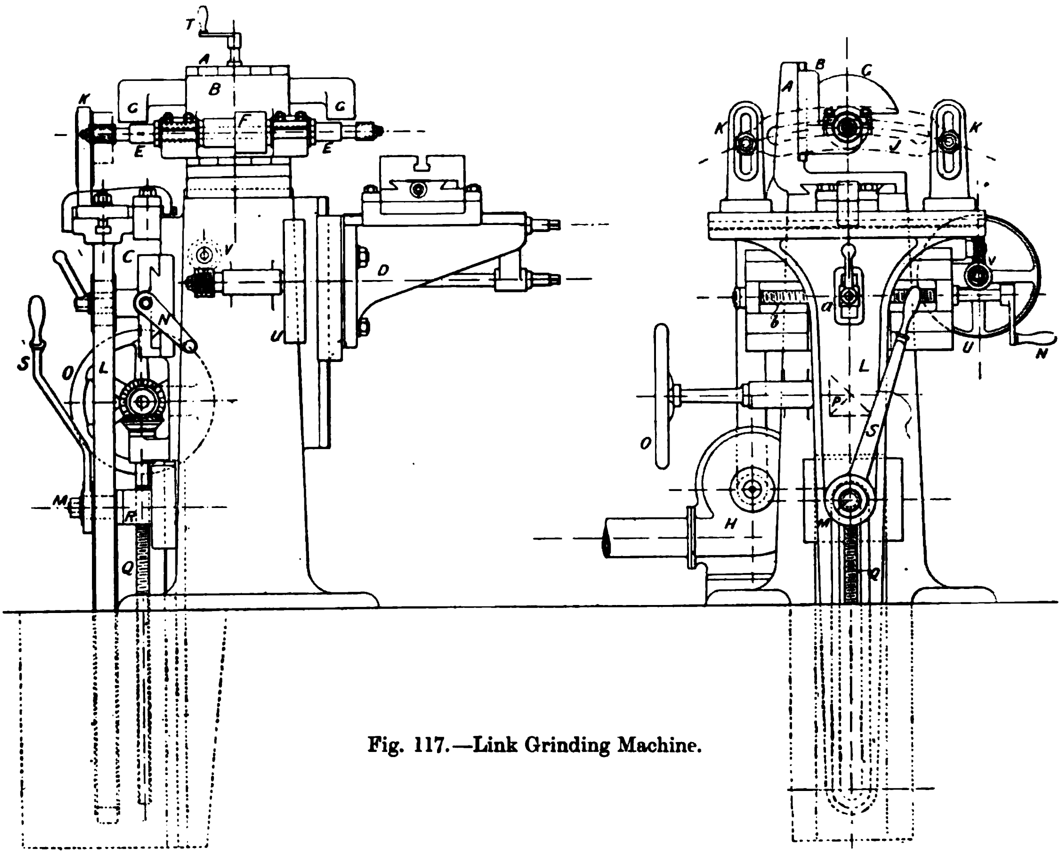


Fig. 117.—Link Grinding Machine.

A vertical link grinder by a German firm, the A.G. für Schmirgel und Maschinenfabrikation, Bockenheim, is shown by Fig. 117. The radial

arm is partly sunk below the floor level. The machine standard has a sliding head A, fitted with a vertical slide B to carry the wheels; A has a movement of longitudinal traverse, B one for vertical feed. There are separate slides for curved, and straight links; C being for the first, D for the second. The movements are by hand, with the exception of the reciprocating motion of the head A. The grinding wheel spindle E is driven by the two-stepped pulley F. The wheels are provided with hoods G, the dust being exhausted by the fan H.

The link J is bolted to the slotted brackets K, K, which are adjustable for centres along the flat end of the radial arm L, which arm is pivoted round the pin M by the handle N, actuating a screw and nut. Radii are adjusted by turning the hand-wheel O, mitre wheels P, screw Q, and nut in R which carries the pivot M. The lever S locks the arm L. The slot in the arm L slides over the nut *a* of the screw *b*, so permitting of the radial motion of the link, when the handle N is turned to effect the traverse motion. The handle T effects the vertical feed of the slide B. The reciprocating movement of the grinding spindle is produced by a belt drive to the pulley U, actuating worm gears V, and a slotted disc and connecting rod within the standard. Straight links are ground on the bracket D, to which the brackets K, K are transferred. The movements of the slides are effected by hand.

Link Motions.—Signifies the usual method of actuating slide-valves by fixed eccentrics, as distinguished from the older designs now nearly obsolete, in which an eccentric, or eccentrics, were moved round their shaft or axle.

In the link motions the movements of the valves are effected through the medium of the links, or *expansion links*, so termed because they regulate expansion as well as reverse. There are several designs of valve gears in which this element is embodied. They may be classified as shifting links, stationary, or fixed link motions, and combinations of both designs. Variations occur in the designs of the links themselves, and their points of suspension. No designs are absolutely perfect, which is the reason why **Joy's Valve Gear** that dispenses with links is used by some railway companies.

The Stephenson Shifting Link.—The elements of this design are the following, Fig. 118. The eccentrics A for forward, B for backward gear, with their respective rods C and D are connected to the link E; F is the valve rod connected to the link by the *die block*, or *sliding block* G. The link E, in mid-gear in the diagram, is moved into its extreme positions for forward and backward gears by the drag link, or *lifting link* H, operated by the reversing arm J, keyed on the reversing shaft or *weigh bar* K, which is actuated by other levers, as convenient, but not illustrated.

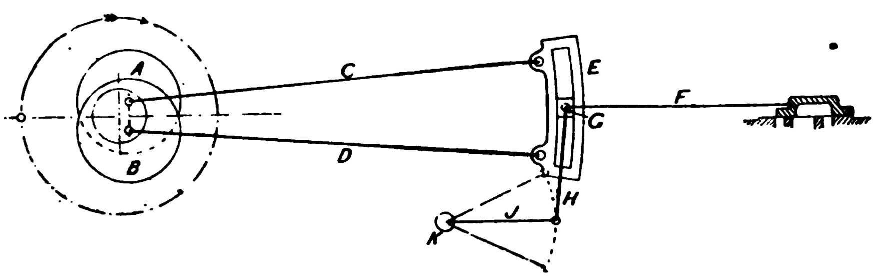


Fig. 118.—Stephenson Link Motion.

The effect of moving the link is to bring the rods C and D either absolutely into line with the valve rod—*full gear*, or approaching thereto; part gear—or expansively, termed *notching up.* Obviously such a design lends itself to much variation in regard to the design of the link, and the location of the lifting, and reversing arms.

It is obvious that when the link is set to full gear in either direction, the action is the same as though the eccentric were operating the valve without the intervention of the link.

But in any other position from mid-gear to full gear the action is modified by the link. In full gear the linear advance of the valve is equal to the lap, plus the lead. But in any other position the lead will vary, being greater or less according to the manner in which the rods are disposed. With *open rods*, that is open when the centres of the eccentrics are on that side of the driving axle which is nearest the link, and crossed when the centres are on that side of the driving axle which is farthest from the link, the lead of the valve is increased as the link approaches mid-gear. This cannot be avoided with such a disposition of the rods, and all that can be done is to make the increase in lead equal on both ends of the stroke of the piston. It is easily demonstrable that the regulation of the quantity of these two amounts of lead depends on the degree of curvature imparted to the link. They are made practically equal by drawing the centre line of the link with a radius equal to the length of the eccentric rods, measured from the centre of the rod at the opposite end.

But though the increase of lead toward mid-gear cannot be avoided, it can be minimised in two ways. First by lengthening the eccentric rods, and second by shortening the effective length of the link, that is the centres at which the eccentric rods are attached to it, and third by diminishing the throw of the eccentrics, all of course being relatively to other parts of the gear.

Crossed rods signifies that the eccentric rods cross each other when the centres of the eccentrics are on that side of the crank axle which is nearest the link. With such a disposition the lead is diminished as the link approaches mid-gear. The amount of this diminution is minimised by the same relative proportioning as that just mentioned in connection with open rods.

In designing a link motion the amount of lead may be fixed for half gear, rather than at full gear. Then the lead is not increased so excessively towards mid-gear, but it is diminished at full gear. To show how to determine the motion of different points in the link would make too great demands on our space. Problems of this kind and others must be sought in works specially devoted to the subject.

Gooch's Link Motion.—This is a motion that provides variable expansion, but with a constant lead. It has a curved link, Fig. 119, A, but the convexity is turned towards the axle, or in the opposite way to Stephenson's. It is a *fixed* link, in the sense that it cannot be raised and lowered, though it swings to and fro in an arc of large radius from a suspension rod, or link B. Practically the dead point *a*, from which it is fastened to the suspension rod, moves in the direction of the stroke of the valve. The sliding or die block in the link is moved up and down in its slot. It is attached to the *radius rod* C, the opposite end of which is connected to the valve stem D. The radius of the curve of the link is equal to the length of the radius rod. The vertical movement of the sliding block is effected by a hanger link E, from a bell crank lever F, as in a Stephenson motion. There are therefore two suspension

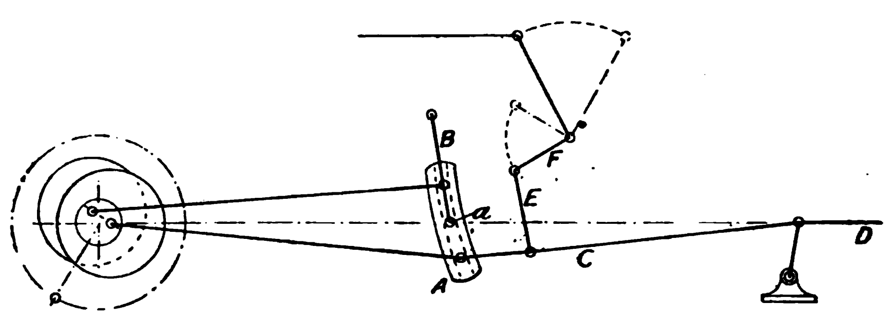


Fig. 119.—Gooch's Link Motion.

links; one, B, which carries the link, the other, E, the radius rod. The point of suspension of the first is fixed, that of the second movable by the bell crank. As in the Stephenson motion, the eccentric rods are made as long, and the length of the link as short as possible.

Allan's Straight Link Motion.—In both Stephenson's and Gooch's link motion the links are curved to an arc; the first with radius equal to the length of the eccentric rods, the second equal to the length of the radius rod, the concavities of the curves facing towards those rods respectively. Formerly, curved links were not tooled so readily as they are now, and it was thought that straight links would be more easily, and accurately constructed. Hence Allan in England, and Trick in Germany, designed a straight link motion. The solution of making the valve move for all grades of expansion equally on each side of a fixed point was obtained by raising or lowering the straight link, and the radius rod of Gooch's gear simultaneously.

In this design, Fig. 120, two eccentrics have their rods attached to the ends of a straight link A. The valve rod link or radius link B on the other side is attached to the block which slides in the slot link. There are two suspension links, one, C, attached to the slot link at its dead point, the other, D, to the radius rod. Both links are connected at their upper ends by a double lever E, which is fixed to the reversing shaft, and rocked by a lever F connected to one on the foot plate. Turning the reversing shaft in one direction lowers the link A, and raises the radius rod B, and with it the sliding block in the link. Turning it in the opposite direction has the contrary effect. In order to obtain equal lead on both strokes for all relative positions of the link and valve rod, the suspension links must be of unequal lengths, in a definite ratio, which is a matter for a lengthy mathematical investigation. The use of a counterbalance weight is avoided in this design, because the levers C and D practically counterbalance each other.

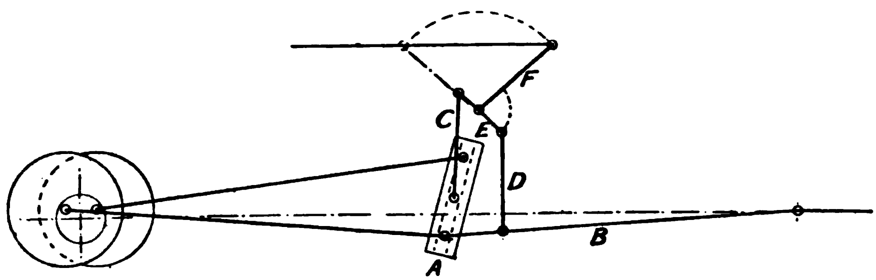


Fig. 120.—Allan's Straight Link Motion.

The objection to Gooch's and to Allan's gears is the necessity for the insertion of a long radius rod to connect the link with the valve rod. This requires a greater distance between the slide-valve and the driving axle than Stephenson's motion does.

Walschäert's Gear.—What the Stephenson motion is in Britain the Walschäert is on the Continent, being fitted, it has been estimated, to about 90 per cent. of new locomotives. It is also fitted on some of the English and American locomotives. It is a very old design, the patent for it having been taken out in Belgium in 1844 in the name of Fischer; Egide Walschäert being a shop foreman in the Brussels workshops of the State Railway. Subsequently a gear theoretically identical was invented in 1849 by E. H. Heusinger von Waldegg. Hence the gear is commonly termed that of Heusinger von Waldegg, or Walschäert's gear. It has been variously modified from time to time. The essential design is illustrated in Fig. 121.

In this gear a single eccentric only is used and set at right angles with the crank. This is a curious arrangement, because it does not provide for lead or lap. The advance required has therefore to be provided by another arrange-

ment, obtained by making connection to the crosshead of the piston rod acting in combination with the movement of the eccentric through a *combining lever*. The effect is to give constant lead whatever the point of cut off. The eccentric is shown in the disguise of a return crank at A, and may be used instead of an eccentric on outside cylinders, and save the space occupied by an eccentric. The eccentric rod B transmits the motion of the eccentric to the link C which swings on a fixed centre *a*. A radius rod D equal in length to the radius of the link is attached to the latter by the sliding block, which block is raised and lowered by a suspension link attached at *b* and moved by a reversing lever. The end *c* of the radius rod is attached to the combining lever E, one end of which lever is attached to the valve spindle at *d*, the other end being rigidly connected to the crosshead F of the piston rod at *e* by a bracket or bar connecting F and *e*. The function of this lever E, with the great disproportion

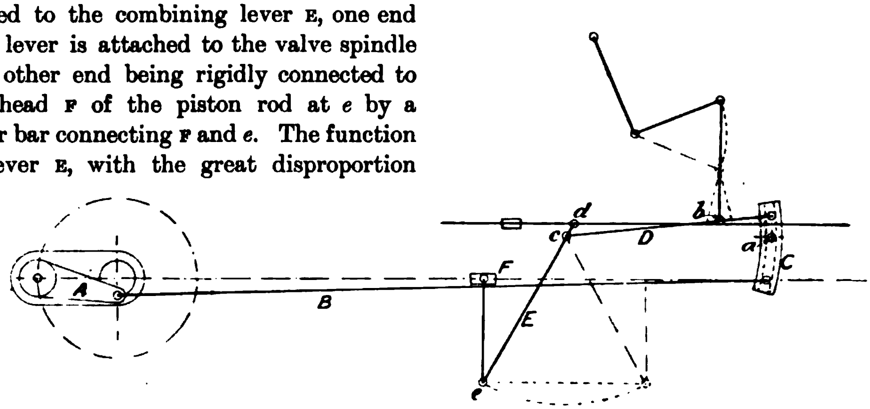


Fig. 121.—Walschäert's Valve Gear.

in length of its arms, is to reduce the stroke of the piston crosshead F, at *d*, to twice the sum of the lead and lap of the valve, on the valve rod at *d*. When the radius rod D is brought to correspond with the centre *a* of the link, the motion of the point *c* will be derived entirely from the crosshead, and the valve will be in its central position at the half stroke of the piston; but by changing the positions of the radius rod D to the upper or lower portions of the link it serves as a forward or backward eccentric. The amount of lead depends on the proportions of the lever E.

The Forms of Links.—The principal forms of links are the box link, comprising two sides and a central space; the slot link, the usual form; and the solid link. An important point is to permit the movable block to be brought right to the centre of the link, which cannot be done if the block lies between the end of the fork of the connecting rod. Hence one reason for numerous variations in details of attachments.

Link Reversal.—Reversal of the direction of motion of an engine by the link, as distinguished from that by a shifting eccentric.

Linseed Oil.—The oil expressed from the seeds of flax. It is used raw, and boiled, the latter being a drying oil. It is an ingredient in oil paints, and is employed for brushing over castings and plated work to preserve from rust until painting can be done.

Liquation.—The separation of the more fusible constituents of alloys during cooling. The most fusible alloys are termed the eutectics.

Liquefaction.—The condensation of steam into water due to cooling action in the walls of steam cylinders working expansively and unjacketed.

Liquid Air. — Air can be liquefied at pressures that range from 1,250 lb. to the square inch to 2,000 lb. and more, in the systems of Ostergren-Berger, Tripler, and Linde respectively. But the energy required is too great to render the methods commercially profitable. In the Pictet system air can be liquefied at a pressure of 15 lb. to the square inch by using liquid air in the process. A bath of liquid air contained in a Dewar bulb or other receptacle receives a coiled tube, one end of which is connected to a hand pump, and the

other bent to discharge into a vessel. Air pumped into the tube at a pressure of 15 lb. to the square inch renders up its heat so suddenly that the liquid air in the vessel boils violently, and the air within the tube liquefies, and flows into the vessel.

As a source of power, liquid air is not able to compete with existing agencies. It has been demonstrated that it takes nine times as much power to produce one gallon of liquid air as can be, even theoretically, developed by one gallon of liquid air employed in a theoretically perfect engine. Also that ten times as much power would be required to operate a refrigerating plant with liquid air as with a carbonic acid plant; besides which the initial outlay is greater. The place of liquid air will lie in other directions. This is partly due to the facility which it affords for obtaining pure oxygen at a low cost. By a process of fractionation, due to the difference in the boiling points of liquid hydrogen and oxygen, a gas which is nearly pure oxygen, or 95 to 98 per cent., is obtainable at a low cost. And liquid air itself is much richer in oxygen than ordinary air. This seems to be the most promising opening for liquid air. Its future may lie in the development of processes in which oxygen is largely used. Liquid air is of value in the laboratory.

In Sir James Dewar's method of producing high vacua, cocoanut charcoal is used to absorb the gas. The charcoal is first cooled to about the temperature at which the gas to be absorbed boils. Liquid air is used at a later stage to cool the vessel containing the charcoal. The power of absorption of cocoanut charcoal for gases is largely increased at the temperature of liquid air. When cocoanut charcoal at − 185° Cent. is saturated with pure dry air it absorbs the oxygen more readily than the nitrogen, the gas recovered at 15° Cent. containing 56 per cent. of oxygen. If the gas absorbed is allowed to escape gradually, a partial separation of the constituents can be obtained.

A gramme of charcoal is able to absorb 450 cubic centimetres of gas at the temperature of liquid air, provided the charcoal is first heated and exhausted to expel gases already absorbed. Any kind of charcoal is a good absorbent, but cocoanut charcoal is best.

Charcoal has a selective absorptivity. Thus if a continuous current of air is passed over charcoal, the discharged gas mixture consists of three volumes of oxygen to two of nitrogen, while that of the air originally was four volumes of nitrogen to one of oxygen. If the charcoal saturated with air were cooled in liquid hydrogen, hydrogen would displace all the oxygen. Many other curious facts bearing on this selective capacity have been recorded by Sir James Dewar.

Researches have been made into the behaviour of iron and steel at the temperature of liquid air, or − 182° Cent. It has long been known that iron and its alloys become brittle at low temperatures. It has been found that the purest and toughest wrought iron becomes as brittle as hardened steel at this temperature, and can be easily broken. If the specimen is allowed to return to its ordinary temperature it resumes its ductility. On the other hand, an iron-nickel-manganese alloy has its tenacity and ductility largely increased, when subjected to the temperature of liquid air.

It has been proposed to use liquid air in the manufacture of producer gas. A mixture of half oxygen and half nitrogen is obtained by liquefying air in a Linde machine, and allowing the liquid air to partly evaporate its nitrogen. This is to be used instead of air. It can be applied to the making of oxygen producer gas, or oxygen water gas, with consequent enrichment of the product.

Liquid air brought into intimate contact with an easily oxidisable vehicle, as coal dust, or charcoal, yields on detonation a powerful explosive mixture. This has been employed in the Simplon tunnel.

Liquid Fuel.—*See also* **Atomiser, Fuels.**—Liquid fuel in its widest sense includes all the natural mineral hydrocarbons, and all organic oils and spirits, as well as coal tar and other products of destructive distillation of coal or wood, but as used in engineering, only the petroleum oils and liquid products of coal distillation are included in the term in a commercial sense. Many attempts have been made to burn liquid fuel by heating it in mass and

exposing it to air. These attempts fail because any heated mass becomes uncontrollable, and no success has been attained, except by the system of supplying the fuel in the form of a fine spray by the aid of steam or of air, or even by the mere feeding of heated liquids through self-spraying nozzles, the fuel being given a whirling movement quite effective in causing it to break up. (*See* **Atomiser**.)

The most usual liquid fuel is crude petroleum freed from the lighter naphthas, &c. Reduced oil has been freed from much of these, and in favour of liquid fuel, which can also be bunkered in less accessible places.

Russian petroleum is the inverse of the American, for while the latter contains 25 per cent. of residuum, the Russian oil contains 75 per cent., and, according to Redwood, Astatki varies from 35 to 60 per cent. of the crude oil, and thus forms the chief product of Russian petroleum. Generally crude petroleum contains many hydrocarbons varying from CH_4 up to $C_{11}H_{37}$, the general formulæ being C_nH_{2n} and C_nH_{2n+2}, but the natural oils vary in every

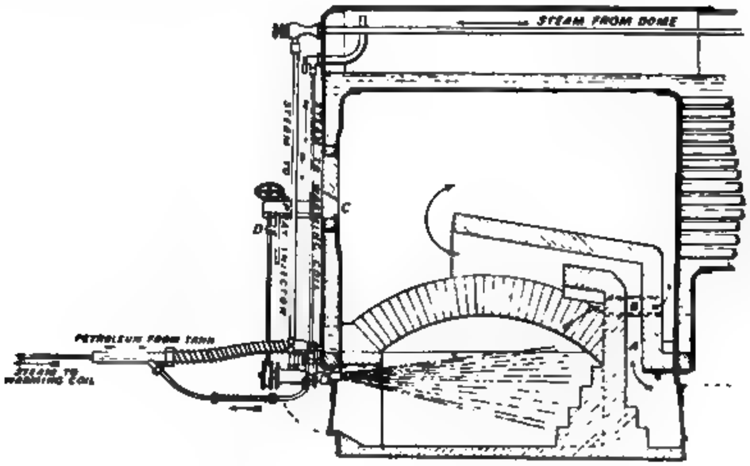


Fig. 122.—Locomotive Fire-box for burning Liquid Fuel.

analyses as follows, A, while distillate fuel oil is of less gravity and analyses as at B. :—

	A	B
Carbon	87·72	86·19
Hydrogen	11·45	12·51
Weight per gallon (10 lb. water)	9·14	85·3
B.Th.U. per lb.	19,800	20,250
Calories per kilo	11,000	11,250
Gravity—Beaumé	23°	34°

Oil being sold by the gallon, that of 23° contains 151,066 B.Th.U. per U.S. gallon of $8\frac{1}{3}$ lb., while that of 34° only contains 143,988 B.Th.U.; or 181,340 and 172,870 respectively, per imperial gallon.

An average fuel oil has a calorific capacity of about one million B.Th.U. per cubic foot, or 35 millions per 35 cubic feet of space, which space would hold a ton of coal of 33 million heat units capacity, showing a slight difference locality (see "Liquid Fuel and Its Combustion," by W. H. Booth).

Of artificially produced oil, creosote is a distillate from coal tar, between crude naphtha and pitch, which comes over at 200° Cent. to 300° Cent. and is slightly heavier than water (1·10 to 1·024). Blast furnace oil has a sp. gr. of 0·988. Shale oil is similar. Most of the coal tar, shale, and wood distillates contain some oxygen, and have a lower calorific value than the petroleums, which are practically pure hydrocarbons. Shale tar has a sp. gr. of 0·865 to 0·894.

The specific heat of Mazut or Astatki is 0·42, so that fuel oils are easy to heat. They expand rapidly with heat, and are thus more easy to rid of water, which becomes relatively heavier while the oil is rendered less viscid, and this helps the water to separate.

Though liquid fuel is nominally but 25 to

50 per cent. more calorific than coal, it can be burned to better advantage, and taken all round is considered to be of double value per pound.

In the combustion of liquid fuel the same general principles obtain which obtain with bituminous coal, but with liquid fuel there is no solid residue to burn on the grate. The whole of the liquid is atomised. The atomised cloud requires to be thoroughly mixed with air, and maintained hot until combustion is fairly complete. There must be no cooling off by too early exposure to boiler surfaces. To secure this end as well as to protect the boiler from too intense local heating, fire-brick linings, dash blocks, bridges, &c., are introduced.

Thus Fig. 122 shows a locomotive fire-box as designed by the late Thomas Urquhart for the Grazi-Tsaritsin Railway. This design includes an ashpan with fire-brick lining, a bridge, and an over-arch with lateral arches to permit flame to get to the side sheets. Thus while the oil is burned in a brick box the flames get all over the fire-box sheet surface. The oil is sprayed against the front wall, and the flames curl round the oven and meet fresh air entering at A. There is a sight hole at C. D is the regulator for the sprayer or atomiser.

In Figs. 123, 124 are shown the Holden system

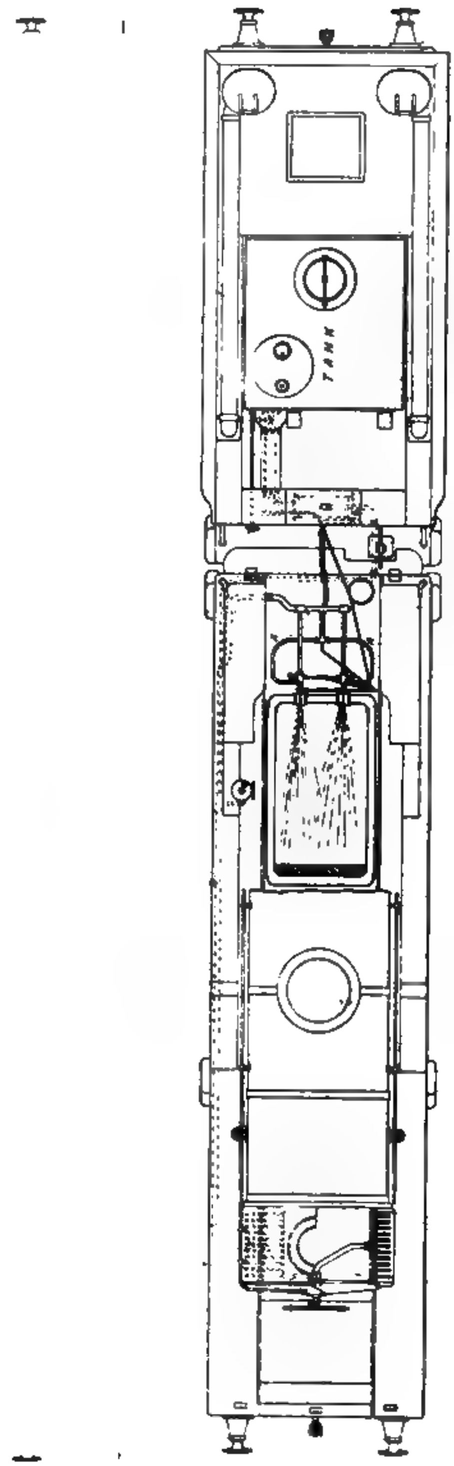


Fig. 123.—G.E.R. Locomotive for burning Liquid Fuel. (J. Holden, Esq., Superintendent.)

as applied to a Great Eastern locomotive. In this system a light fire of coal and broken fire-brick is kept upon the grate, and two injectors, Fig. 125, spray the fuel towards the front wall under the brick arch. The bed of coal prevents serious variation of temperature in the fire-box when oil is shut off, and also ensures ready ignition when the oil supply is turned on. The oil is warmed when necessary by a steam coil in the fuel tank of the tender. The following particulars, taken over a period of twelve months, show the relative consumption of fuel of two express locomotives, the one burning liquid fuel and coal, and the other coal only:—

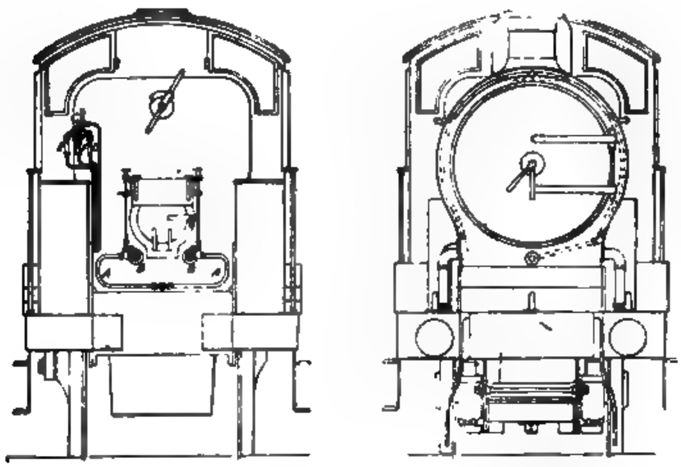


Fig. 124.—G.E.R. Locomotive. End Views.

	Total Mileage for 12 Months.	Consumption of Fuel per Mile.		
		Oil.	Coal.	Total.
		Lb.	Lb.	Lb.
Liquid-fuel engine	37,033	18·8	9·5	28·3
Coal-burning engine	33,067	Nil	39·3	39·3

At Fig. 126 is shown an American locomotive fire-box 8 ft. long, the tube-plate and side sheets being brick lined in the lower parts, and there are air inlets from the ashpan, which is lined. There are no bars and no coal fire, and the fuel atomiser points slightly upward to the rear of the arch. There is only room for one atomiser in these narrow fire-boxes.

The application of liquid fuel to the furnace of a Lancashire boiler is shown at Fig. 127. Here there is a protective ring of brick forming an oven round the spray as it enters, with an air inlet from below. There is a dash wall a few feet forward, and two further brick baffles perforated. These various obstructions retard the flow of flame and give time for combustion to become complete. With solid fuel the resistance of the fire on the grate is the chief obstruction to the draught. With liquid fuel, this being absent,

Fig. 125.—Injector for G.E.R. Locomotive.

there is no need for any serious draught; and oil fuel permits of much larger blast pipe orifices, and in locomotive work the variable blast cap of Macallan is employed. Sometimes a small lighting-up grate is employed in locomotive work. This occupies only a fraction of the grate surface, and serves to carry a fire to help in getting alight the liquid fuel.

For water-tube boilers a furnace of fire-brick has been employed, in which the spray of fuel is directed towards the fire-brick bridge, and fresh air is admitted in the angle of the bridge and arch as well as from the furnace floor. It is open to doubt if the over-arch is long enough, so that at times there might be smoke formed by too rapid cooling of the flames by the cold-water tubes.

The foregoing are designs on which there are many variants, and in marine work the same principles were employed in the case of a steamer by the Wallsend Slipway & Engineering Co., fitted with the Körting atomiser, and full protecting fire-brick linings. The oil is heated to 266° Fahr., and issues at a pressure of 50 lb. per square inch from the nozzles. When atomising with steam or air these agents also should be hot. High-pressure steam is better than low-pressure. An American expert, Mr C. O. Billow, considers that steam atomising should be done for 3·3 per cent. of the total steam made, and that a positive air blower will supply air for atomising for only 1·36 per cent. of the boiler output of steam, but if air is compressed beyond 30 lb. absolute the steam required may be as much as 6 per cent.

As regards burning liquid fuel above solid fuel, M. Bertin, of the French Navy, considers that the liquid fuel uses the excess of air which comes through the solid fuel, and that the economy of air is considerable in consequence. He says that 5 kilos. of coal will produce ordinarily 39,000 calories, and will use 20 cubic meters of air in excess, and this would supply all the oxygen wanted for 1 kilo. of oil, which would yield 11,000 calories with no further air supply. The mixing effect of the atomiser is such that the coal now produces 46,000 calories, or 7,000 more than ordinarily, and the addition of the oil appears therefore to yield 18,000 calories, so that oil is made to appear worth 2·31 times as much as coal, whereas the coal has really given some of the extra heat.

M. Bertin found that the limit of perfect use of air is found when the oil is one-third of the coal, for the ordinary 4 cubic meters of air excess still furnishes the 11 cubic meters needed by the oil, and their relative equivalence now appears as 1 : 1·95. At half and half mixture it becomes 1 : 1·77. The chemical minimum of air per pound of oil is 15 lb., but usually an excess upon this of 33 per cent. will be the minimum that can be employed in practice.

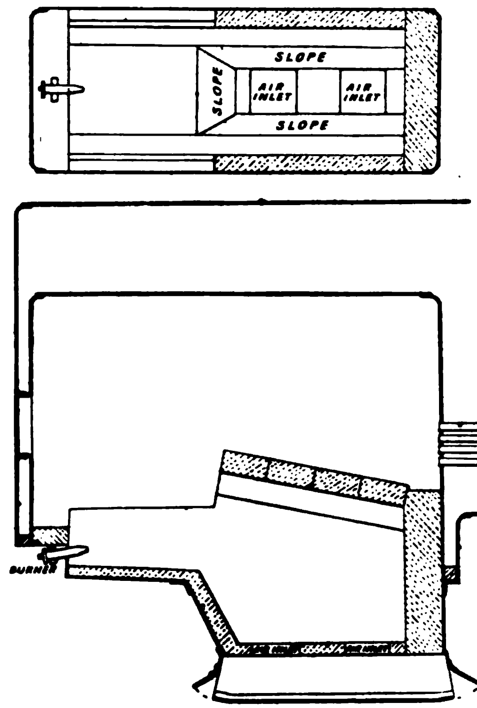


Fig. 126.—American Locomotive Fire-box for burning Liquid Fuel.

Much argument has been expended upon the relative merits of steam and of air for atomising purposes. Though it is incorrect to award any credit to steam as a combustible substance, as some have done in the past, it is certainly open to be argued that steam may produce some chemical effect in the way of promoting the union of the hydrocarbons with oxygen.

In American practice oil is maintained at 20 lb. pressure in the pipe system by means of pumps and suitable by-pass return valves to

deal with any surplus pumped. A pumping system consists usually of a pair of duplex pumps, brass fitted and mounted with an oil receiver on a cast-iron drip pan. The receiver has two compartments, in one being fine gauze filters upon perforated tubes projecting into the chamber. The other chamber is usually two-thirds full of water, and contains a live steam coil, and the pumped oil flows through the hot water and is thereby heated on its way to the atomisers. Though, as regards the principle, a water pump will pump oil, this pre-supposes that the oil must not be too thick or viscid, for cold oil flows badly, and oil must be warmed if with a much smaller force of men, an advantage which does not hold where there is mechanical stoking, but still holds good so far as its power extends to the getting of more work from a given number of boilers. Or the load peak could be passed by the aid of small tube boilers of the Solignac type, holding very little water, and capable of full steaming output within five minutes of turning on the liquid fuel. Oil fuel may be used when a fog comes on to get up the steam suddenly wanted.

The following advantages as compared with coal may finally be quoted from an article by Mr H. Tweddle. There is less loss of heat up

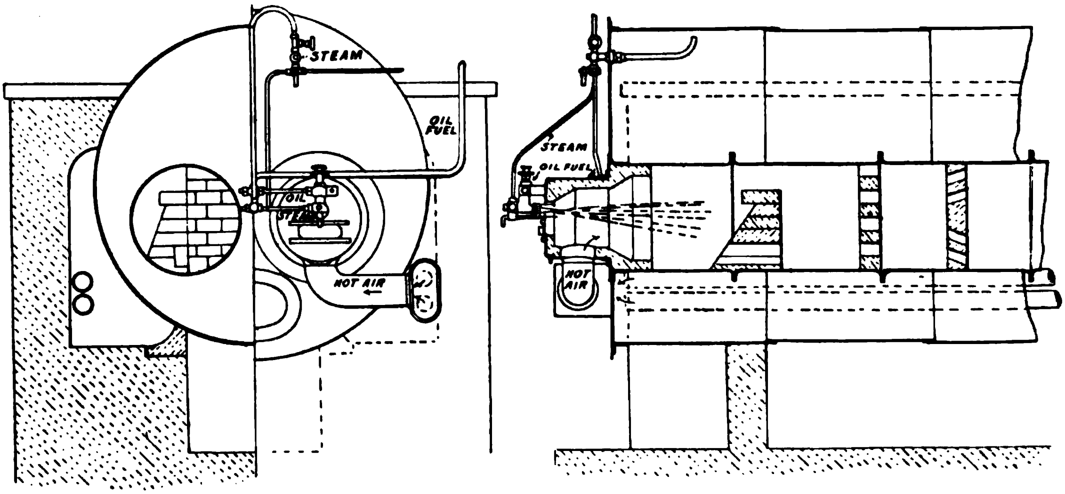


Fig. 127.—Lancashire Boiler fitted for burning Liquid Fuel.

it is to flow at all freely through pumps of either piston or centrifugal form.

Liquid fuel forms a very small fraction of the world's total supply of fuel. It can never come into universal use, but its employment will be confined to particular cases. Liquid fuel can be got to the boilers from inaccessible bunkers in a way quite impossible with coal, and in a warship the 1906 manœuvres of the British Fleet proved its value conclusively when Admiral May, with his stokers tired out, put on liquid fuel, ran away from the pursuing fleet, and escaped up channel, laying figurative waste of every town along the coast.

In an electrical station the peak of a lighting load could be passed by means of liquid fuel the chimney owing to clean surfaces and reduced air supply. Heat is more equally distributed, fire-doors have not to be opened, and there is less straining and higher efficiency. There is no danger of dirty fires on a hard run. The cost of fuel handling is less. No grates or fire tools are needed. The furnaces therefore last longer. There is no dust, ashes, or clinker. Petroleum does not deteriorate by storage. Fires are easy to regulate and control. There is less manual labour required, and the steaming capacity is increased by 35 per cent.

Mr Tweddle also speaks as to the absence of sulphur, but this does not hold good, for much liquid fuel has more sulphur in it than ordinary coals have, and it all goes into the gases,

whereas with coal the sulphur goes largely into the ash or clinker.

Liquids.—*See* **Boiling, Diffusion, Evaporation, Hydraulics, Hydrostatics, Solution.**

Litre.—A litre is the unit of capacity—dry and liquid—in the **Metric System**. It is the volume of a cubic decimetre. The weight of this quantity of distilled water at its maximum density, 4° C., is a kilogramme. The equivalents of the litre in British measures are:—1·76 pint, ·88 quart, ·22 gallon, in liquid measure; and ·113 peck, ·027 bushel in dry measure; and in volume it equals 61·027 cubic inches, or ·035 cubic foot.

Live Axle.—A driving axle.

Live Head.—A term often applied to the fast head of a lathe.

Live Load, or **Dynamic Load.**—A load which is being incessantly imposed and removed; a varying or repetitive load, which may include a narrow or a wide range of stress. Though the difference in live and dead loads was recognised by a Railway Commission in 1847, the reason of the difference in the two was not understood until the Report of Wöhler on repetitions of stress was published in 1871. Previous to this the belief was held that a live load caused more deflection, and therefore more stress than a dead load. Wöhler showed that the *nature* of the two kinds of loadings was of an entirely different character. A bar or structure will carry a purely dead or statical load even though it be a large fraction of its breaking load for an indefinite period without fracture, and without increased deflection. The strength is also increased by straining beyond the elastic limit. But with live loads the results are different. These come under two heads, those in which repeated stresses are of one kind only, and those in which they are of opposite kinds. Repetitions of stress of the same kind increase the elastic limit. But repetitions of alternating stresses do not. For if it is raised in one direction as in tension, it is lowered in compression. The main essential fact deduced from Wöhler's experiments, and which has had most marked results in practice, is that safe working cannot be based on the *maximum* stress which a bar or structure will endure; but on the *range*, or *amount of variation* of stress. The range determines the number of repetitions which a bar will bear before fracture. Below a certain limit a bar will endure an almost infinite number of repetitions before fracture. Above that limit the number of repetitions is less, and they diminish with increased range of variation of stress.

Approximately also a bar strained in one direction only will endure twice the stress which it can sustain when strained in opposite directions. Such bars when they break show a brittle fracture. The result of these researches is that varying limits of working stress are made to depend on the range of variation of stress.

Live Rail.—A steel rail fixed upon insulated supports in the centre or at the side of

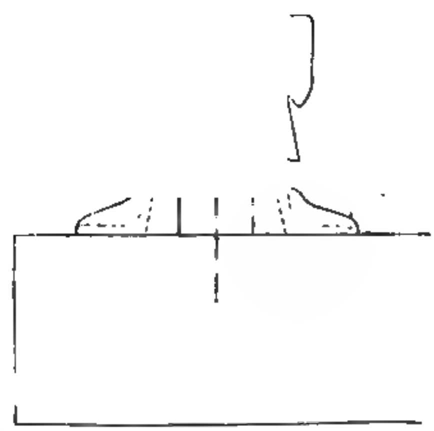


Fig. 128.—Live Rail. (Dick, Kerr, & Co., Ltd.)

the running track of an electric railway. The live rail carries the + current, which is collected therefrom by a rubbing shoe or skate attached to the travelling car, passing through the motor and returning by way of the wheels to the running rails which form the − return path to the generating station (*see* **Electric Traction**).

The difficulties of effective insulation for a conductor under these conditions have been overcome by the design of special insulators, a

type of which, manufactured of reconstructed granite, is illustrated in Fig. 128. This design represents the insulator used on the Lancashire and Yorkshire Railway Company's electrified Liverpool-Southport line, and has been found satisfactory during some years that the line has been in use. The live rail is flanged, the parts below forming the base and deflecting hoods of the insulator, isolating it from contact with earth.

All the electric railways installed so far in this country utilise the live rail system, but in some projected electrifications it is proposed to use single-phase alternating currents and overhead conductors, when the live rail will not of course be required.

Live Ring.—A set of rollers having a conical section in the longitudinal axis, arranged in a circle between top and bottom paths, and used where large masses have to be rotated, as in swing bridges, turn-tables, and large revolving cranes. The rollers may run loosely in their paths or *races*, with some lateral play, or they may be maintained equidistantly by fixed rods or spindles. In the latter case the rods or spindles are supported in rings within and without the rollers. The amount of coning is determined by the radius of the ring, the apex of the cones being located at the centre.

Live Rollers.—*See* **Live Ring.**

Live Spindle.—A spindle which revolves. Applied to the mandrel of a lathe headstock.

Load, Loading.—The imposition of a weight on a structure. In estimating loads the weight of the structure itself must be included. Loading is broadly classed as of a dead or live character.

Load Factor.—The relation between the average actual output of a central power station during a given period, to the maximum capacity.

Loam, Loam Board, Loam Bricks, &c.—*See* **Loam Moulding.**

Loam Moulding.—Generally, the sweeping up of a plastic mixture of sand by the edges of a board, attached to, and swept round a central bar, the loam being supported by a mass of brick-work. An example is shown which will make a suitable text for observations on loam work in general.

The example given in Figs. 129-134 is that of a large crane drum swept up with its axis vertically. The first stage is shown at Fig. 129, in which the plate A, prodded, and having lifting lugs, and shown separately at A in Fig. 135, is laid on timber blockings B. The striking bar C, in its step D sunk into the floor, carries the sweeping board E, to which it is bolted by the strap. The plate A is levelled, and the top edge of the board also, first planed at exact right angles with the end that abuts against the bar. Loam is daubed on the prods of the plate, and bricks bedded on this, over which the final coat of fine loam is swept. The spaces between the bricks are ample, to ensure venting, which is facilitated by filling with fine cinders, and a space at F is also filled with cinders for the same reason. G is the joint, corresponding with the middle of the flange.

For the upper half of the flange, and to carry the bricks which form the body of the mould, a ring is cast, prodded on both sides, and on its inner edge, and a thickness of loam swept on one of its faces. This stage is not shown separately, but the ring is shown at H in Fig. 130, and in place in the finished mould in Fig. 133. It has of course been turned over in Fig. 130, which represents the succeeding stage; G is the joint just made between the mould in Fig. 129 and the corresponding portion just stuck on the plate H. The prods which now come on the upper face of H receive the bricks J for the main body of the mould, against which loam is swept by the board K. The flange mould at *a* is filled with loose sand while the board K is sweeping the body. The board strikes a check at *b* which centres the top or cope mould. This is struck, Fig. 131, on a plate L, shown also separately in Fig. 135. It differs only from the bottom plate A in having holes cast for runners and risers. The board M differs only from the board E used for the bottom, in having a cheek to match *b* in Fig. 130.

The central core is swept as in Fig. 132. The plate which carries it, shown at N in Fig. 135, has lifting rods cast in it, and is prodded on both sides. A plain layer of loam is first swept on the lower face and dried, and then laid on the bottom of the mould, while the ring body is being removed and dried. Plenty of fine cinders

are laid in the joints of the bricks, and the central annulus, o, is filled with cinders to form a collecting place for the gas. Loam bricks are laid at intervals in plan between the hard bricks to permit of shrinkage of the core. The board P can only be carried at its upper end.

The finished mould is shown in half section in Fig. 133, to the right, and in half external view to the left. The plan view of the pouring arrangements is seen in Fig. 134. It is shown as placed in the pit. The cope and bottom parts are secured with cramps Q gripping on the bottom and top plates A and T. Vents *c* come up from the bottom, produced by ramming rods in the sand,

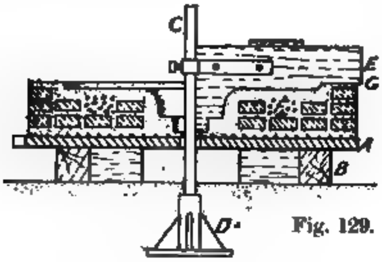


Fig. 129.

Fig. 133.

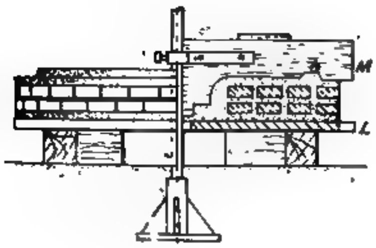


Fig. 131.

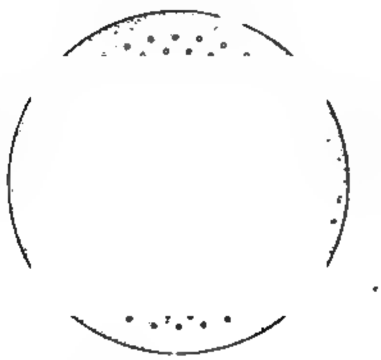


Fig. 134.

Figs. 129–134.—Stages in Loam Moulding.

and withdrawing them as the ramming proceeds. Pouring is done through an annular basin R, and ring of runners, the metal therefore falling to the bottom of the mould. It is formed between cast-iron rings laid on the top plate. S is a flow-off basin, *dd* are feeding holes for the boss, and a central vent is provided.

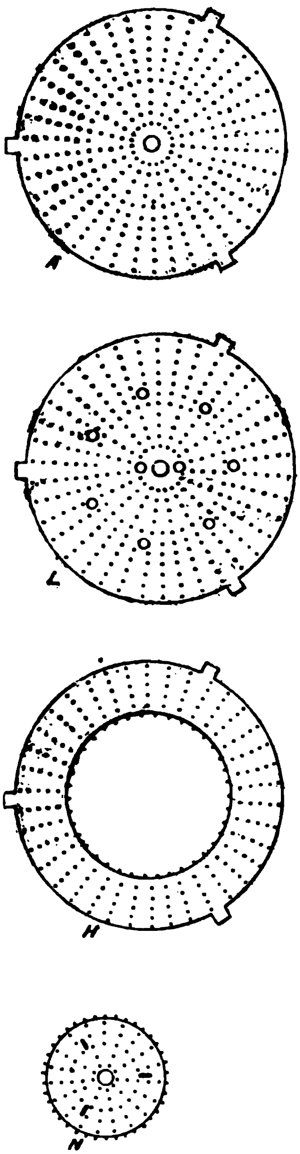


Fig. 135.—Loam Plates.

The following remarks relate to the practice of loam work as a whole.

Loam.—Loam is a dry, strong, sand mixture, to which horse dung, or cow-hair, or tow, or straw are added, the dung being most commonly used. It is a binding material, and the drying of the mould carbonises the particles of undigested hay, leaving the mould porous, hence loam moulds are not vented with the wire, as a rule, except in awkward corners. The sands are ground with clay wash, and made of coarser or finer grades for first rough coats, and final finishing ones respectively, and also varying with different classes of work.

Loam Plates.—Loam moulds must be swept up on suitable plates. These are of cast iron, Fig. 135, varying from 1 in. to 3 in. thick, according to the diameter and mass of the mould. Prods are cast on the face to hold the loam on which the first course of bricks is bedded, and lugs at the edges for lifting by. Successive layers of bricks break joint, and each one is separated from those adjacent by a thick layer of coarse loam, with or without fine ashes, according to locality. A thickness of about 1 inch of loam facing the mould is usually sufficient. Joints between different portions of moulds are made with or without checks. Large cores are swept up similarly to the outer mould. From these general statements we now offer some remarks relative to details of this class of work.

Pressure in Moulds.—It is apparent that the pressure in deep moulds would be too great to be resisted by a body of bricks alone, enclosing the moulds. All deep moulds are, when finished, rammed up in a pit of sand, Fig. 133, to support the sides, so that the bricks shall not be thrust outwards by the expansion due to heat, and the liquid pressure. Occasionally castings become wasters through this cause, the metal running away. But when rammed round with sand, its exit, should such begin, is arrested directly, and the casting saved. But the pressure and strain of a very heavy casting could not be resisted by a single row of bricks without distortion occurring. Two rows must then be used, to break joint, the inner row against which the loam is struck being made up of broken bricks, as being stronger, and as affording more joint space for the escape of the gases than the whole bricks would furnish. To bind these together still further a layer of headers is set at intervals of every two or three courses. In deep moulds at about every half dozen courses, a ring of cast iron is built on the bricks, affording a continuous bond of union.

Drying Moulds.—Since the moulds have to be dried very thoroughly, and as this can only be done in a stove or in a suitable pit, the height of deep moulds has to be borne in mind. When the depth of the mould is so great that it cannot be put into the stove entire, as often happens with the cylinders of marine and pumping engines, it is divided into two portions by means of a cast-iron plate having lugs. No check is usually required for accurate replacement for casting, a straightedge sufficing to set the parts by. But when portions, as facings

or branches, have to occupy exact vertical relations in each, the moulder marks two or three vertical lines with the edge of the trowel on each section before separation, which remain as guides for setting by after drying.

The method in which a loam mould is lifted is by a large cast-iron cross, and from which depend slings that embrace the lugs on the plate.

Cores.—A bricked-up core differs from an external mould in this respect, that the broken bricks face outwards towards the loam. The interior of a bricked-up core is filled with loose ashes before closing and casting, Fig. 132, to occupy space which would otherwise become

Fig. 136.—Cast Ribs bolted to a Loam Plate.

filled with air, that would burst out with explosive force on the entry of the metal. The space being already occupied with ashes, the air from the mould is quietly carried off as fast as it is generated. Cores are often swept up on a skeleton of cast-iron ribs, Fig. 136, supporting bricks, the ribs being bolted to the bottom plate.

Checking Dimensions. In struck up loam work it is common to find dimensions at fault if proper care is not exercised in the setting of the boards. In sweeping flat surfaces the plan of making the top edge of the board parallel with the horizontal plane of the mould, and checking with a spirit level, is a good precaution which should always be adopted, Figs. 129 and 131. The end of the board which abuts against the bar should be as square as possible also with that edge. But in the case of boards for deep cylindrical work this mode of checking is not feasible, either for the outside or for the core. It is necessary then to check diameters at the time of striking up. A strip gauge is used to check the inside diameter of a cylinder, the strip being notched at the centre to fit the bar closely. A wooden caliper is employed for checking the diameter of a core. There will sometimes be a variation of ½ inch in diameter at the top and the bottom of a deep mould caused by the swaying over of the bar, due to bad fitting in its seating. Long bars are for this reason sometimes provided with a bearing at the top. One source of a discrepancy that is sometimes found between the calculated length of the board and the actual diameter of mould which it strikes is to be sought in the bad form given to the strap. One edge of the strap should be continuous with the centre line of the bar, and the striking edge of the board should be set against that face. But it is easy to see that if the strap is made central, and the striking edge set away from that face, a very considerable difference in diameter is at once made, which will amount to ⅜ in. or ½ in. in a small mould.

Thickness of Loam.—A greater thickness of loam should be used for corners and projecting portions of moulds than for broad flat surfaces. In those sections of moulds which are liable to scab it is better to use loam bricks than ordinary bricks, since they furnish a porous body through which the gases are able to escape, thus preventing bubbling of the metal against the surface. Loam should be swept or built of as uniform thickness as possible over the faces of the bricks. From ⅝ in. to 1 in. should be the average thickness. A very thin layer will be apt to cause scabbing due to the flaking off of the loam.

Casting.—Loam moulds, like cores, must never be closed for casting until pouring is about to take place. A loam mould is like a core in this respect, it absorbs moisture from the air. If a mould steams when taken from the stove it is not dry enough for casting. It is better to wait a day longer than run the risk of a waster through dampness of the mould. All the fastenings and vents of the core must be seen to as carefully as those in any green sand mould.

Bedding in Pattern Parts.—In all but the very plainest swept-up work, the use of sectional portions of patterns is essential. But loam moulders avoid the use of wood when practicable, employing them in necessary cases only, or taking them from the mould when circumstances will allow before the mould is baked hard. The reason is, first, that loam does not strip kindly from a wood surface, but clings to it in patches, even sometimes when the surface has been oiled. Loam also causes the wood to swell and warp, throwing it out of truth, and producing lapping joints, which distort and tear the mould; and since the wood is often embedded in its damp environment for several days at a time, the evil is to an extent unavoidable. Again, in the baking in the stove the loam absorbs some of the oily matter from the partially desiccated wood, and this prevents its taking kindly to the water necessary for mending up, and making broken parts good.

Again, when wood sections are concerned, their upper portions are formed, not by the sweeping of the loam on the bricks, but by the daubing of the loam first on the wood, and then by the setting of the bricks in and on this loam, at the same time loaming the joints themselves. Unless care is exercised, the setting of bricks one after the other, and one above another, amidst so yielding a bedding as loam, is apt to cause the shifting of those which have been already set, and with them a loosening and distortion of the loam, causing it not to be of equal consistence throughout. Neither is the surface produced in contact with wood, so true and smooth as one which is swept up by successive applications of loam directly applied. A swept-up surface is of more equal consistence, more uniform, less patchy, and less liable to scab than one formed against wood. Still, when flanges, prints, brackets, ribs, &c., are required in moulds, they must in most cases be prepared in wood, and when the surface becomes damaged it must be mended up, any oil present being scraped and washed away, and wet loam stuck on.

Where there are overhanging and weak edges of loam it is necessary to leave the portions of the pattern upon which they rest in the mould until it is partially or wholly dried. If the portions were removed while the loam was wet, it would sag or fall out of place. Any pattern pieces thus dried in place must not be varnished, because the loam would stick to them. When bedding wood patterns, or portions of the same in wet loam, an application of oil should be given them to prevent the sticking of the loam thereto. All weak corners should be rodded as in green sand moulds. The rods should be secured in the wet loam by packing them with pieces of broken bricks, or of loam bricks.

Loam Work not Swept up.—There is a good deal of loam work that is not swept up, but is simply made from skeleton patterns. In making a condenser body, one way would be to make a pattern and core boxes. But a better way is to make a framed-up or skeleton pattern, the thickness of the stuff in which is the same as that which the casting is intended to be. The core is first built within, and strickled flush with the inside of the strips. Then the thickness of the wood in the framing is made up level with sand to the outside face, and against this the outer mould is built. When dried, the latter is taken away, the frame unscrewed, and removed in pieces, leaving the core standing. When the mould is complete and put together again, the thickness is necessarily the same as that given in the skeleton pattern, the thickness namely of the casting. This is much better than using a pattern and core box, because even if made to correspond exactly in the first instance, the latter may become distorted in opposite directions, thus producing unequal thicknesses, while a skeleton pattern, if it "goes" at all, must go altogether in the same direction, leaving the thickness unaltered.

Loam Patterns. — Foundry patterns of large dimensions swept up in loam to save the cost of making them in wood. They are struck up like common circular cores on a horizontal bar, rotated in the core trestles against the edge of a sweeping board. Stiffening plates are used as in cores. The economical value of this lies in the saving of timber, and pattern-maker's time. It is usually also less costly than making a mould in loam. A loam pattern will with care endure a large number of mould-

ings from; frequently, however, only one or a few moulds are required. Only circular work, and work without weak edges can be swept up thus. Hence deep flanges and all brackets and other attachments have to be constructed of timber, and laid upon and secured to the loam pattern. The moulding from such patterns is done like that from other patterns, by bedding in, or turning over. But there can be no joint in the pattern, dividing it in halves. It is usual, however, to scribe a line round in the middle section as a guide to the moulder to joint the mould by.

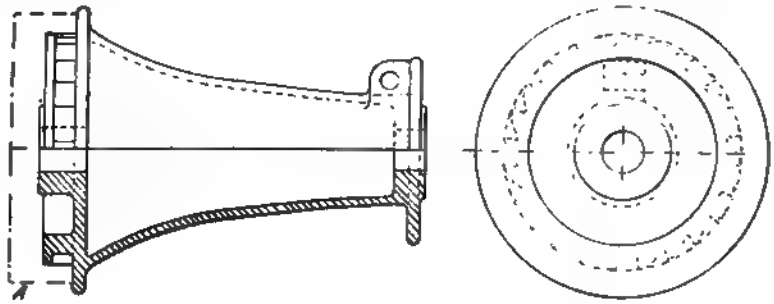


Fig. 137.—Casting to be made.

Figs. 137, 138 illustrate the making of a loam pattern. Fig. 137 is a casting of a fusee drum for a derrick crane to be moulded on its side from a loam pattern. This is slightly complicated by the fact of a ratchet being cast on one end. This is therefore made in cores (not shown), and these must be laid in a print impression, the outlines of which are indicated by the dotted lines at A. Fig. 138 shows the loam pattern, with the board against which it has been swept up. The core print at A corresponds with the outline of the same dotted in the previous figure. The pattern is struck on a bar B, which is an ordinary core bar used for convenience, though the vent holes are not required. Cast-iron plates are wedged on the bar, seen in the half-sectional view, to support the hay bands wound between them, also seen in section, and between and over all which the body of loam is swept. The flange at the left standing out but slightly beyond the loam body is also swept in that material. But the flange C to the right would become broken away, and this, therefore, is made in wood, and fitted over the core print there. The lug D, which could not be swept, is made in wood, and fitted. The position of the flange is marked on the board at E, to indicate to the moulder its position on the pattern.

Lock Nut.—When machinery is subject to vibration, it is necessary to provide means of locking the nuts on bolts and studs to prevent them from working loose. There are numerous ways of accomplishing this end, and new devices are constantly being brought out, but

Fig. 138.—Loam Pattern Work.

there are a few well-tried methods that find general favour. The use of two nuts, Fig. 139, A, is very common, the lower nut being first screwed up, and the upper one then tightened down upon it. Theoretically the strain comes chiefly on the top nut, and that should be the thicker one, as at B, but that plan necessitates

the use of a thin spanner, and many prefer to tighten up the lower nut very hard, and so put a thick one there for strength. Occasionally both nuts are of full thickness. Split pins are sometimes passed through an extension of the bolt end, in the event of the nuts working loose, to prevent them from falling off and dropping the bolt. A transverse set-screw forms another method of locking; it should not bear upon the screw threads because of the damage caused thereby, but may pass through and press upon a plain turned extension of the screw C. A better arrangement is that shown at D, where the nut is turned down into a shouldered collar, receiving the point of a set-screw passed in laterally. It may be recessed into the piece, or may stand up, E, and be prevented from turning by a set-screw in an encircling ring, secured with a vertical stud. Slotted or "Castle" nuts, F, have grooves cut across their ends, between which split pins pass from the bolt and prevent rotation. The split pin passes into any grooves that lie in line; should the nut be subsequently tightened up, another pair will be brought round. G is a nut partly slit through and fitted with a small set-screw, which draws the split portions together, causing sufficient friction of the nut upon the screw to lock it. A device for locking large nuts is shown at H, that of a plate embracing three flats, and secured with a set-screw after the nut has been tightened up.

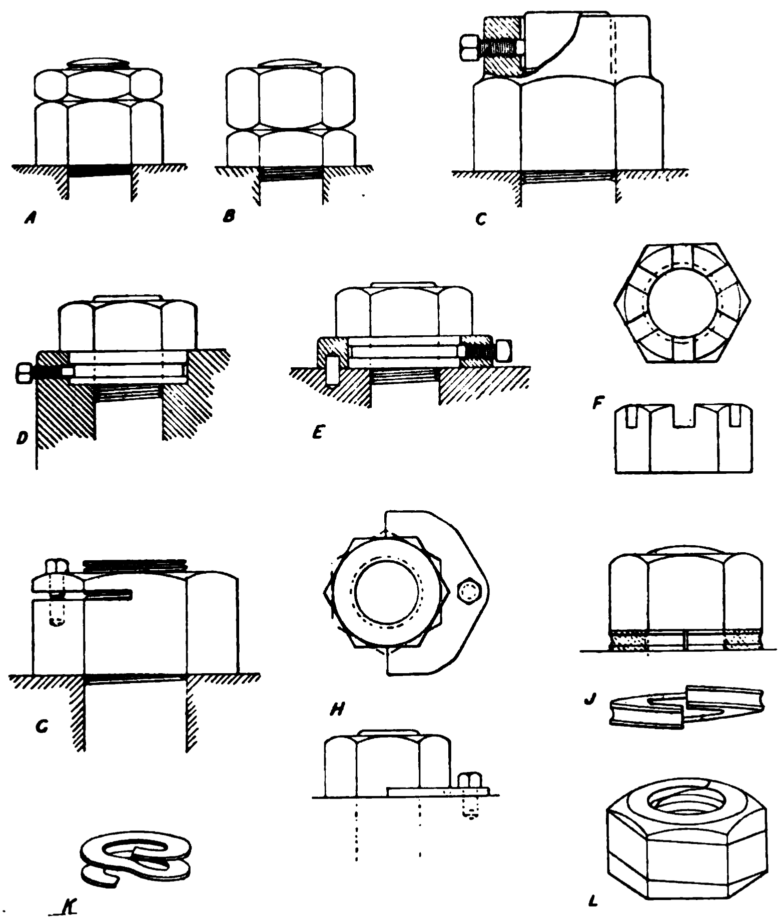


Fig. 139.—Lock Nuts.

The action of a spring is utilised in several types of lock nuts. The advantage is that slackness is automatically absorbed, and lengthening of the bolt compensated for. The Grover spring washer is one of the most successful devices, and consists of a ring, split through and bent into the form shown in J. On placing it under the nut and screwing down the latter, the washer exerts a constant pressure upwards. A chisel cut can be made across the face of the nut, and of the work for additional security. A somewhat similar washer is the Thackray, K, in which the turns are increased. The helicoid nut combines nut and lock in one, L; it is made by winding special sectioned steel into spiral form, cutting off, and tapping to form nuts. The tapping is done slightly small, so that some force is required to screw the nut down, and this opens the turns a little. As the surface of the work is

reached, the spiral is put into compression, and so locks itself securely.

Lock-Up Safety-Valve.—One with a cover or bonnet, which is provided with some form of hasp through which a padlock can be passed and fastened. Done commonly to prevent tampering or overloading.

Locomotive Boiler.—*See* **Locomotive Engine.**

Locomotive Engine.—*Leading Characteristics of Modern Practice.*—The aim of engineers has been to improve the constructional details of the locomotive and its capacity as a whole, rather than to make any radical alteration in its design. Its recent development has been in the direction of obtaining a large increment of power in conjunction with greater economy, and different designers have endeavoured to effect these ends in various ways. The compounding and superheating of the steam, and the use of very large boilers, high steam pressures, and relatively small cylinders and small driving wheels are among the more common methods now resorted to for the purpose of securing higher all-round efficiency. The most striking advance made within a comparatively short period has been in the increased size of the boiler, and it is now generally recognised that the steaming capacity, as the primary source of power, should be as large as possible, having regard to the haulage requirements of the engine. The demand for locomotives capable of drawing heavier loads at higher speeds than formerly has thus led to the employment of larger and heavier types. The bigger boilers have entailed more weight, and in many cases this extra weight is borne by additional wheels, which in some instances are driving wheels, but in others simply carrying wheels. The principal types of locomotives in use are briefly referred to later, and are classified according to the number and arrangement of the wheels.

It will be convenient, however, to first make some mention of the leading features of present-day practice, in so far as certain principles and details are concerned.

Compounding, and Superheating.—These are dealt with under their respective headings, but it may be stated *en passant* that opinion is still divided as to their merits. Compounding is in considerable favour on the Continent, to a lesser extent in America, and to a still smaller degree in Great Britain, where, however, one or two engineers are again taking the subject up. Practically the same may be said with respect to superheating, with the qualification that it is not as yet of such general application as compounding. At the present time, compounding and superheating in conjunction are being tried experimentally in Belgium.

Cylinders: Diameter, and Piston Stroke.—In the case of British non-compound locomotives, the tendency is, with the present high steam pressures, to employ cylinder diameters ranging from 18 to 20 in., but 19 in. is by far the more usual size. In a few cases 21-in. cylinders are used. On the Great Western Railway, the standard diameter is now only 18 in., but additional power is obtained by employing the unusually long piston stroke of 30 in. On most other British lines the normal stroke is 26 in. In certain recent examples the stroke is 28 in., and in others, again, it is only 24 in. In this connection, nothing definite can yet be expressed as regards British practice, but it may be mentioned that a piston stroke of 28 in. is now very general in America, and even one of 32 in. is used for freight engines. Owing to the greater height, and width of the loading gauge, very large boilers are possible in the case of American and Continental locomotives, and hence the cylinders of such engines are frequently of a greater diameter than is usual in this country. A few British locomotives are running with four high-pressure cylinders, in order to obtain a better balancing of the revolving and reciprocating weights, but the majority of four-cylinder engines, both here and abroad, are of some compound type. On the Midland and Great Central Railways respectively three-cylinder compounds are at work.

Position of Cylinders.—Although the practice of placing the cylinders outside the frames is all but universal abroad, it has not become general in Great Britain. The Great Western Railway, however, appear to have definitely adopted the outside plan, which is also followed by other lines where circumstances render it necessary or expedient. Still, a large number of new and powerful engines have inside

cylinders, and there does not seem to be any marked or general tendency to depart from that practice.

Piston Valves.—These are used in many modern American and Continental locomotives, but the ordinary D slide finds the greatest favour in this country at present, although a few British engines are fitted with cylindrical valves.

Valve Gear.—The Stephenson link motion continues to be generally used in Great Britain and America. But in both countries the Walschäert gear, common on the Continent, is being employed to a greater extent than formerly.

Driving Wheel Diameter.—The requirements in the way of additional tractive power have been partly met by using relatively small driving wheels. Some English engineers still prefer 7 ft. wheels for fast express work, but the majority adopt diameters ranging from 6 ft. 6 in. to 6 ft. 9 in. For goods and mixed traffic, the diameters vary from 4 ft. 6 in. to 6 ft., according to the speed required. The boiler is now the chief governing factor in wheel diameter in this country, since the loading gauge prevents the use of large driving wheels and boilers of large diameter conjointly. The American and Continental loading gauges permit of greater latitude, but the driving wheels of foreign engines are seldom made as large as 7 ft. at the present time. Some American express locomotives have wheels only 5 ft. 8 in. in diameter, but from 6 ft. to 6 ft. 8 in. are the more ordinary sizes.

Boiler.—Generally speaking, no change has taken place in the design of the boiler, except where it has been modified to adapt it to superheating, or the use of water tubes in the fire-box. As regards recent British practice, the diameter and length of the barrel show a considerable advance. A large number of engines have been built with boilers 5 ft. 6 in. in diameter, practically all of them being for express duty. On the other hand, several engineers as yet content themselves with boilers of a maximum diameter of approximately 5 ft. 3 in. The Great Western Railway have adopted as a standard the American extended wagon-top type, in which the rings are conical, with increase in circumference towards the throat-plate. The larger of these boilers have a diameter of 4 ft. 10¾ in. at the front, and of 5 ft. 6 in. at the fire-box end. The barrels have a length of 14 ft. 10 in. On other lines, the length of the barrel, in the case of modern engines, varies from 11 ft. 10 in. to 17 ft. 7⅞ in., the longer boilers being used for engines having ten wheels. With the bigger boilers, it is customary to use four safety-valves. The tubes usually correspond in length with the barrel, but in a few instances the front tube-plate is set back, the length of the tubes being thereby reduced (*see* Fig. 150). Tubes having an external diameter of 2 in. are used in many new British engines. Large boilers are employed on the Continent, but the diameter does not often exceed 5 ft. 6 in., but it must be noted that either compounding or superheating is usually adopted. In America, on the other hand, huge boilers are the rule, irrespective of any other feature. For recent heavy types of express engines, the diameter varies from 5 ft. 10 in. to 6 ft., and the length of the barrel from 16 ft. to 21 ft. For large freight locomotives, the boilers are often 6 ft. 9 in. in diameter, and in exceptional cases 7 ft.

Fire-box.—The Belpaire fire-box is a distinctive feature of large numbers of locomotives, both here and abroad. In America and on the Continent the *wide fire-box*, the sides of which rest on the frames, has grown in popularity, and fire-boxes of this type have lately been introduced into this country (*see* Figs. 152, 156).

Heating Surface.—For heavy work in this country the total heating surface is now usually not less than 1,900 or 2,000 sq. ft., and several engines are running with from 2,250 to 2,500 sq. ft. The grate area varies from 20 to 31 sq. ft. These figures are surpassed on the Continent and in America. In the case of exceptionally large freight engines in the United States, they are more than doubled, while heating surfaces of from 3,000 to 4,000 sq. ft., and grate areas of from 50 to 55 sq. ft., are now by no means unusual for American express locomotives.

Weight.—Modern British and Continental engines mostly weigh from 60 to 75 tons, exclusive of the tender. The weight of the

PLATE VIII.

Fig. 142.—Express Passenger Engine.

Fig. 144.—Engine with Extended Fire-Box.

Fig. 145.—Combined Compound Engine with Walschaert Gear.

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tender varies from 40 to 57 tons. From 3,500 to 5,000 gallons of water, and from 5 to 8 tons of coal are carried. In America, the larger types of express engines weigh from 80 to 100 (British) tons, and in some instances more than 100 tons, while the tenders, which hold from 5,000 to 7,000 imperial gallons of water, and from 10 to 15 tons of coal, vary in weight from 60 to 75 tons. The weight of freight engines varies according to the type, but it does not greatly differ from that of the passenger locomotives, where the number of wheels corresponds.

The table below gives the principal types of locomotives in use. The classification figures denote the number and position of the various wheels. A dash (—) separates the carrying from the driving wheels. Thus a 4—4—2 engine is one with a four-wheeled leading truck, four-coupled drivers, and a pair of carrying wheels at the back. A cypher indicates the absence of carrying wheels at one or both ends of the engine. For instance, a 0—8—0 engine means one in which all the wheels are coupled together, while a 2—8—0 signifies one with eight-coupled wheels, and a pair of carrying wheels at the front. Tank locomotives are omitted for the reason that their wheel arrangement resembles that of tender engines, with the exception that the trailing end may be supported on a single radial axle, or on a four or six-wheeled truck. Only the more important types are listed.

As it is impossible here to illustrate these types with many drawings of representative engines, a few examples are given, comprising outlines and photographs selected from the designs of Mr H. A. Ivatt, of the Great Northern Railway. They illustrate many of the foregoing remarks.

Passenger Engines.—Fig. 140 shows an express passenger engine of the 4—4—0 class, particulars of which are printed underneath it. Fig. 141 is a much more powerful engine. The front tube-plate, it will be noted, is brought back into the barrel. Fig. 142, Plate VIII., is a photograph of the same engine. Fig. 143 is a similar engine with larger boiler and wide fire-box, the sides of which rest on the frames. Figs. 144 and 145, Plate VIII., are photographs of the same type of engine "Atlantics," four-coupled, with differences. Fig. 144 is a simple engine, Fig. 145 a combined compound type with Walschäert gear for high-pressure cylinder, shown in detail in the drawings, Figs. 152 to 156. A ten-wheeled side tank engine for local traffic is shown in Fig. 146, and its photograph in Fig. 147, Plate IX.

Goods Engines.—Fig. 148 is a main line goods engine. The front tube-plate comes back

PRINCIPAL LOCOMOTIVE TYPES.

Type.	Classification.	Service.
Single driving wheel, without bogie	2—2—2	Moderately heavy express trains on easy gradients.
Single driving wheel, with bogie	4—2—2	,, ,, ,, ,,
Four-coupled, with single leading axle	2—4—0	,, ,, ,, ,,
Four-coupled, with leading bogie	4—4—0	Heavy expresses on normal gradients.
*Four-coupled, double end, "Columbia"	2—4—2	Ordinary expresses on normal gradients.
"Atlantic," four-coupled	4—4—2	Heavy expresses on normal gradients.
Ten-wheeled, six-coupled	4—6—0	Heavy expresses on steep gradients.
*"Prairie," six-coupled, double end	2—6—0	Ordinary passenger and goods.
*"Pacific," six-coupled, twelve wheels	4—6—2	Heavy and fast expresses on steep gradients.
Six-coupled, six wheels	0—6—0	Normal British engine for light goods.
"Mogul," six-coupled, leading truck	2—6—0	Moderately heavy goods.
Eight-coupled, eight wheels	0—8—0	Heavy goods.
"Consolidation," eight wheels and leading truck	2—8—0	,, ,,
*"Decapod," ten wheels and leading truck	2—10—0	Heavy goods on steep inclines.
*Twelve-wheeler, leading 4-wheeled truck	4—8—0	Heavy goods.
*Articulated, twelve wheels, all driving wheels	0—6—6—0	Extra heavy goods on mountainous roads.

* Not yet used in Great Britain.

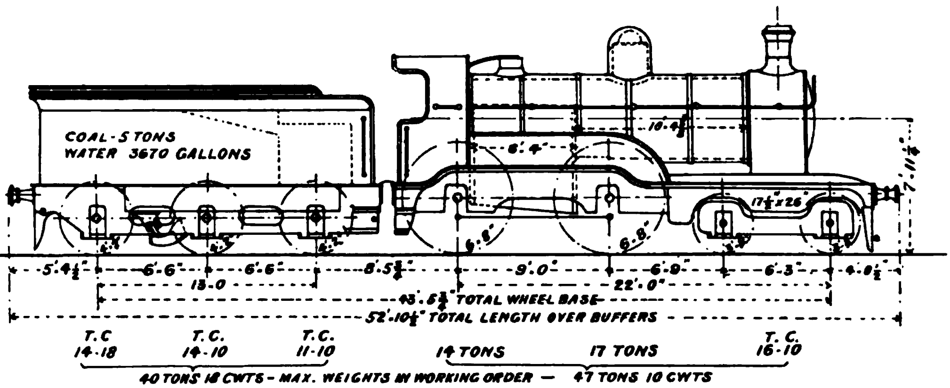

Fig. 140.—G.N.R. Express Passenger Engine 4—4—0 Class.

Heating Surface—Fire-box, 120 sq. ft. } Total, 1,250 sq. ft.
Tubes, 1,130 ,,

Grate area, 19 sq. ft. Working pressure, 170 lb.

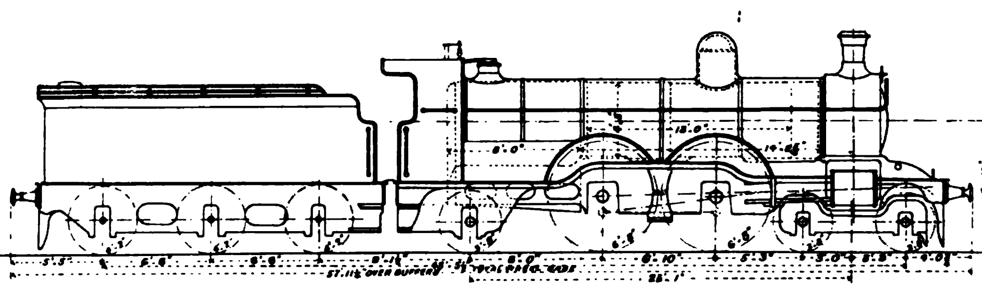

Fig. 141.—G.N.R. Four Wheels Coupled Express Engine

Heating Surface—Fire-box, 140 sq. ft. } Total, 1,442 sq. ft.
Tubes, 1,302 ,,

Grate area, 24·5 sq. ft. Working pressure, 175 lb.

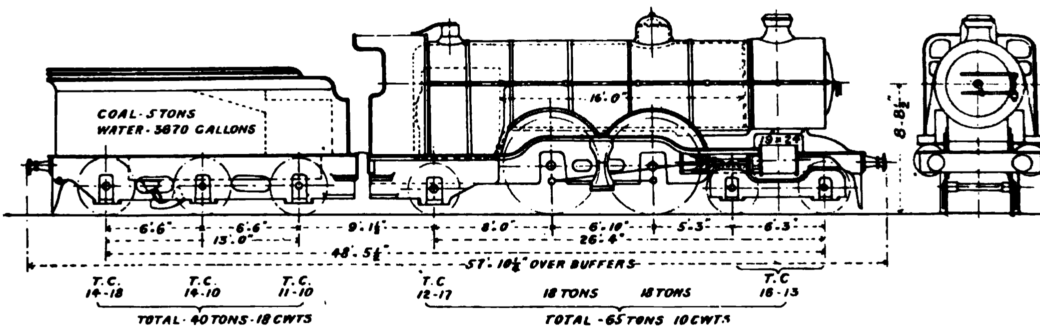

Fig. 143.—G.N.R. Express Passenger Engine.

Heating Surface—Fire-box, 141 sq. ft. } Total, 2,500 sq. ft.
Tubes, 2,359 ,,

Grate area, 31 sq. ft. Working pressure, 175 lb.

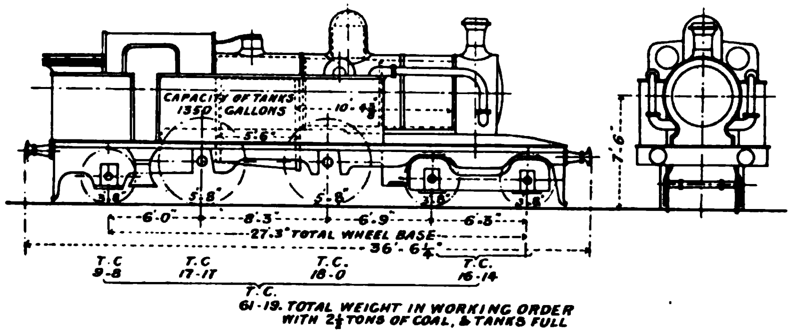

Fig. 146.—G.N.R. Ten-wheeled Side Tank Engine. (Cylinders, 18 in. by 26 in. stroke.)

Heating Surface—Fire-box, 103 sq. ft.
Tubes, 1,016 ,, } Total, 1,119 sq. ft.

Grate area, 16 sq. ft. Working pressure, 170 lb.

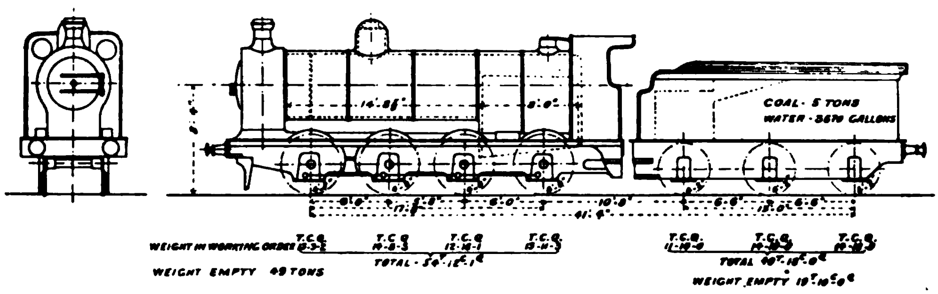

Fig. 148.—G.N.R. Eight Wheels Coupled Goods Engine. (Cylinders, 20 in. by 26 in. stroke.)

Heating Surface—Fire-box, 136·75 sq. ft.
Tubes, 1,302 ,, } Total, 1,438·75 sq. ft.

Grate area, 24·5 sq. ft.

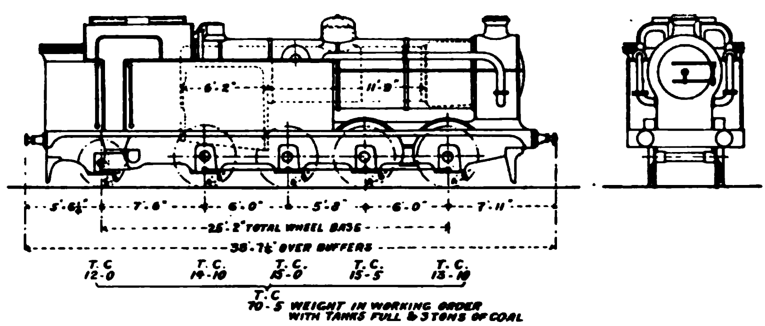

Fig. 150—G.N.R. Eight Wheels Coupled Side Tank Engine. (Cylinders, 20 in. by 26 in. stroke.)

Heating Surface—Fire-box, 107·7 sq. ft.
Tubes, 936 ,, } Total, 1,043·7 sq. ft.

Grate area, 17·8 sq. ft. Working pressure, 175 lb. Contents of tanks, 1,500 gallons.

[illegible] Great Northern Railway (H. A. Ivatt, Esq., Locomotive Engineer).

Fig. 153.—Half Vertical Section through Cylinders, and Half External Elevation of Front of Engine.

Fig. 154.—Cross Section through Boiler Barrel and Motion Bars

Fig. 155.—Half Vertical Section through Driving Wheels.

Fig. 156.—End Elevation at Foot-plate End

End Elevations and Sections of Great Northern Express Passenger Engine.

within the barrel. The boiler is similar to that in the engine shown in Fig. 141. It is also shown by Fig. 149, Plate IX. Fig. 150 is a very heavy engine with side tanks, shown also by the photo in Fig. 151, Plate IX., also with tube-plate set back in the barrel.

Figs. 152 to 156 illustrate an "Atlantic" type locomotive designed by Mr Ivatt to work continuously, either as a simple or a compound, for hauling the heaviest Scotch expresses, and the fast service for the towns of the West Riding. The boiler is worked to a pressure of 200 lb. It has 141 sq. ft. of heating surface in the fire-box, and 2,359 sq. ft. in the tubes, making a total of 2,500 sq. ft. There are 248 tubes, $2\frac{1}{4}$ in. in diameter, with liberal spacing. The details of construction are clearly seen. A special feature is that the large grate area of 31 sq. ft. is obtained without undue lengthening of the fire-box by extending the box laterally over the trailing wheels. The boiler is 16 ft. long between the tube-plates. The barrel is made of steel, $\frac{3}{4}$ in. thick. The fire-box is of copper, $\frac{9}{16}$ in. thick, the fire-box tube-plate is $\frac{3}{4}$ in. thick. The tubes are of iron. The fire-box is 5 ft. 11 in. long, by 6 ft. 9 in. wide.

The compound engines comprise four cylinders—two high pressure of 13 in. diameter and 20 in. stroke situated outside the framing, and two of 16 in. diameter and 26 in. stroke inside it. These can be worked either single or compound continuously by means of a *change valve* placed over the steam chest of the inside cylinders. When working simple, the change valve admits high-pressure steam to both sets of cylinders, and discharges the exhaust of the outside cylinders into the blast pipe. When the valve stands in the position for compounding, it cuts off the boiler steam from the inside or low-pressure cylinders, and turns the exhaust from the outside or high-pressure cylinders into the inside steam chest; the steam passes on its way round the inside of the smoke-box. The change valve is worked by a small auxiliary steam cylinder in connection with a water dashpot, arranged to lock it in either simple or compound position.

The valves on the outside cylinder are Richardson's balanced, with the back cut out between the strips, so that the exhaust goes straight through. The steam chest is between the inside cylinders. The valves are balanced by strips working against a rubbing plate placed between them. The outside valve gear is of the Walschäert type (*see* **Link Motions**), the inside gear is ordinary link motion. Both are worked from two reversing levers close together on the foot plate. Each reversing shaft can be locked from the foot plate by means of a vacuum lock similar to a vacuum brake placed on the middle of the shaft, and designed by Mr Ivatt.

The total weight of the engine in working order is 69 tons. That of the tender is 40 tons 18 cwt. The driving axles are each loaded to $18\frac{1}{4}$ tons. The bogie carries $18\frac{1}{2}$ tons. The engine wheel base is 26 ft. 4 in., the driving wheels are 6 ft. 8 in. in diameter. The bogie and trailing wheels are 3 ft. 8 in., and the tender wheels are 4 ft. 2 in. diameter. The tender has a coal capacity of 5 tons, and a water capacity of 3,670 gallons.

Compressed Air Locomotives.—These are used chiefly in mines and situations where smoke and fire are objectionable or dangerous. Their range is comparatively limited, but is sufficient for the purpose required. The power is derived from a store of compressed air carried in a tank or tanks above the framing, in the same situation as that occupied by the boiler of a steam locomotive, and the cylinders and motion work are practically the same as those for steam, compounding being often done. The cylinders are usually ribbed on the bodies, to absorb heat rapidly from the surrounding air. The pressures in the storage tanks range from 500 to 2,000 lb. per square inch, depending on the space available for the tanks. If there is plenty of head and side room, large tanks may be used with air at the lower pressures, but if space is very limited, smaller holders must be used with the air at a very high pressure to carry sufficient volume. Re-charging is done from stations to which tubes are connected up, the operation only taking a minute or so. The air is sometimes reheated on the loco. by tanks of hot water obtained from the charging stations.

Compressed air has been used to a limited

Fig. 147.—Side Tank Locomotive Engine.

Fig. 149.—Main Line Goods Engine.

Fig. 151.—Heavy Goods Engine.

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extent for tramway engines, notably in Paris, where numbers are still running.

Electric Locomotives.—In the earlier days of electric railways direct haulage of the passenger coaches by an electric locomotive was adopted. Later developments, however, are upon the self-contained unit principle—that is, each coach is fitted with independent motors, and may be operated independently; or alternatively a number of such coaches may be coupled together to form a train, the whole being controlled by a master-controller on one of the cars.

This "Multiple Unit System" has proved to be so much more convenient and economical than the locomotive system, that, at any rate for passenger traffic, the latter has been entirely displaced. For working of goods traffic the locomotive is necessary, and is often used for shunting operations where electric power is available.

The growing application of electric power in mining operations has found work for the electric locomotive, and where circumstances permit, the haulage of trucks used in coal mines is preferably done by an electric locomotive. Wherever it is practicable in coal mines to provide an overhead trolley wire, this system has great economical advantages over the use of haulage ropes, otherwise often required for main roads, or the use of ponies for the side roads. Some powerful and very compact designs of electric mining locomotives have been evolved. The storage-battery locomotive has in some instances been tried, but the trolley wire is of course preferable.

Locomotive Crane.—A crane which has provision for self-propulsion. It is a portable crane, but a portable crane may not be a locomotive crane, since a hand-operated crane mounted on a truck on wheels is portable.

Steam Cranes.—Generally the locomotive type has, until recently, been steam driven. The difference between the fixed and locomotive steam cranes often consists in the addition of a truck and travelling gear to a fixed superstructure of a firm's standard type. There is an extra set of gear and shafts for the travel, which connect from the engine shaft to bevel gears in the truck, driving to the travelling axles, the details of such connections varying in designs by different makers. In a design better adapted for heavy service, as that in steel works, the travelling is done by a pair of engines on the truck, distinct from those on the side frames. The weight of these engines being low down is favourable to the stability of the crane. The breakdown cranes are often of locomotive type. But they differ from ordinary cranes in being fitted, like rolling stock, to the requirements of the railways. Locomotive cranes are used on gantries, being then termed gantry cranes.

Figs. 157 and 158, Plate X., illustrate typical locomotive cranes.

Electric Cranes.—These vary like other cranes in the method of taking the current from an overhead wire, or from between the rails, or from one side. The bevel gear drive to the trolley wheels is retained. A single motor used with gears, or three motors are fitted, one for hoisting, and derricking, another for revolving, the third for travelling.

Locomotive Hoist.—A tripod used in running sheds for the purpose of lifting one end of a locomotive carriage or wagon, for effecting repairs to axle boxes, and the removal or insertion of wheels. The legs are of timber, or steel-plated, with cast-iron shoes and plated straps. The hoisting is done by gearing fixed on two of the legs, or from a crab on the ground. Powers range from 10 to 35 tons.

Log.—A trunk of a tree in the round with branches lopped off. When squared it is a balk. The term is only applicable to trunks not less than about 12 inches in diameter. Logs are sometimes used for piles and other purposes, but as a rule they are squared, or sawn into planks before the timber is used.

Logarithm.—Logarithms were invented by John Napier in 1614, and generations of practical mathematicians and scientists have been indebted to him for this great labour-saving discovery. By the use of logarithms the process of (*a*) multiplication is changed into that of division, (*b*) division into subtraction, (*c*) involution into multiplication, and (*d*) evolution into division.

The logarithm of a number to a given base

is the index of the power to which the base must be raised in order to give the number. Thus $4^2 = 16$, and $10^3 = 1,000$; then 2 is the logarithm of 16 to the base 4, and 3 is the logarithm of 1,000 to the base 10. For many reasons it is convenient to adopt 10 as a base, and this was done in 1615 by Briggs, a contemporary of Napier. Since:—

$10^1 =$ 10,	the logarithm of	10 is 1
$10^2 =$ 100,	" "	100 is 2
$10^3 =$ 1,000,	" "	1,000 is 3
$10^4 =$ 10,000,	" "	10,000 is 4.

The logarithms of all intermediate numbers above 10 will obviously consist of decimals as well as the whole numbers 1, 2, 3, 4, and so on; for instance the logarithm of 12 is 1·07918.

The logarithms of the numbers between 1 and 10 will consist only of decimals.

The logarithm of 1 is 0, and therefore the logarithm of any number less than unity is a negative quantity. This is denoted by the placing of a minus sign over the whole number or integral part of the logarithm; for example, the logarithm of ·0002 = $\bar{4}$·30103. The decimal part of the logarithm is called the "mantissa" and the integer is termed the "characteristic."

In tables of logarithms the characteristic is omitted, mantissæ only being given, and these without the decimal point. The following table shows how the logarithms of the numbers 1 to 20 are set down.

No.	Log.	No	Log.	No.	Log.
1	00000	8	90309	15	17609
2	30103	9	95424	16	20412
3	47712	10	00000	17	23045
4	60206	11	04139	18	25527
5	69897	12	07918	19	27875
6	77815	13	11394	20	30103
7	84510	14	14613	...	...

The logarithms of all numbers from 1 to 200,000 have been calculated to six or seven places of decimals. Sufficient accuracy is obtained, however, with four or five places only. In using tables the decimal point must be supplied, and the characteristic, if any. The latter may be found by inspection, for since the logarithm of 10 is 1; of 100, 2; of 1,000, 3; of 10,000, 4; it is clear that the characteristic of a number greater than unity is one less than the number of figures in the integral part of that number. Thus the characteristic of:—

84321	(5 integers)	= 4
8432·1	(4 ")	= 3
843·21	(3 ")	= 2
84·321	(2 ")	= 1
8·4321	(1 ")	= 0.

If the number is less than unity the characteristic is a higher number by one than the number of noughts that follow the decimal point, and is negative as stated above. Thus the characteristic of:—

·843	(no nought)	= $\bar{1}$
·0843	(1 nought)	= $\bar{2}$
·000843	(3 noughts)	= $\bar{4}$.

It now remains to show how certain processes are simplified by the use of logarithms, and this will be best illustrated by taking the small numbers in the table given above. This will be sufficient to demonstrate the manner in which the processes of multiplication, division, involution, and evolution are changed into those of addition, subtraction, multiplication, and division respectively, and the saving of labour and time in dealing with larger and unwieldy numbers will be easily imagined.

Required the product of 5 and 4. From the table,

$$\begin{aligned} \text{Log. } 5 &= \cdot 69897 \\ \text{Log. } 4 &= \underline{\cdot 60206} \\ \text{Total} &= 1\cdot 30103 \end{aligned}$$

By reference to the table, the total, 1·30103, is found to be the logarithm of 20, the product required. The product of any two numbers may thus be found by adding their logarithms and finding from a table what number the sum of these logarithms represents.

Required to divide 100 by 5,

$$\begin{aligned} \text{Log. } 100 &= 2\cdot \\ \text{Log. } 5 &= \underline{\cdot 69897} \\ \text{Difference} &= 1\cdot 30103 \end{aligned}$$

The difference, 1·30103, is seen to be the logarithm of 20, the quotient required.

Fig. 157.—Locomotive Steam Crane. (Thomas Smith & Sons.)

Fig. 158.—Locomotive Steam Crane. (Thomas Smith & Sons.)

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Required to find the fourth power of 2, or 2^4,

$$\begin{array}{r} \text{Log. } 2 = \cdot 30103 \\ 4 \\ \hline \text{Product} = 1\cdot 20412 \end{array}$$

And this product is the logarithm of 16, the number required.

Required to find the fourth root of 16,

$$4)\underline{1\cdot 20412} = \text{log. } 16$$
$$\cdot 30103$$

The quotient ·30103 is the logarithm of 2, which is the fourth root of 16.

Log Frame Saw.—A heavy type of vertical reciprocating saw for breaking down logs into deals, flitches, planks, or boards. It comprises a framing within which a *swing frame*, or *saw gate* moves up and down, and carries a number of saws, varying from 1 to 50, held in by buckles and cotters, which divide the log up as it is passed through. There are two methods of feeding in the logs, by what is termed roller feed, Fig. 159, Plate XI., and by rack feed, Fig. 160, Plate XI.; the first-named employs fluted rollers which grip the log and propel it along while it is supported upon rollers mounted on standards suitably located. The second uses a travelling carriage running on rollers in bearings on timber beams, the carriage being racked along by pinion. The roller feed is very satisfactory for even and regular logs, and allows them to be passed through rapidly in succession, but on crooked and irregular logs the rollers are unable to get a proper and continuous bite, especially if they are wet or frozen, so that the carriage becomes necessary. This involves running it back after each pass in readiness for a fresh log, and some time is wasted by comparison with the roller feed.

The methods of driving include bottom and top drives, and direct steam drives. The first carry a crankshaft below the floor, driven by belt pulley, and working a connecting rod at the centre, or two outside rods, coupled to the saw frame. Where space is limited below, the crankshaft is placed on top of the framing, working thence down to the frame. A steam cylinder is also used in certain cases, with its piston directly connected to the centre of the saw gate. Electric motors are being employed in many instances, operating the crankshafts, above or below, without the intervention of belting.

The feeds of rollers or carriages are produced by what is called the silent ratchet, or V-wheel, worked from the reciprocations of the saw gate, or from an eccentric on the crankshaft, rocking a lever to which is connected an eccentrically shaped pawl which jams into the vee of the wheel, and gives it a partial turn at each stroke, as the saw frame rises, slipping round on the reverse motion. The amount of movement is variable.

Long-Armed Cranes.—Generally applied to the newer types of cranes with long horizontal jibs, or runways for handling coal and cargo.

Long Columns.—Columns of from 25 to 30 diameters in length and upwards. These do not fail by crushing but by cross bending. Their strength therefore depends on the coefficient of elasticity, or capability of resisting flexure. The load which produces moderate flexure is very near the breaking weight. The strength varies directly as the fourth power of the diameter, and inversely as the square of the length. The advantage of flanges, as lessening liability to flexure, is evidenced by the fact that a long flat-ended column has the same strength as a round-ended column of half the length, and that the relative strengths of long columns of equal length with both ends rounded, and with one end flat and the other rounded, and with both ends flat, are nearly as 1, 2, 3 respectively.

Long D-Valve.—*See* **D-Valve.**

Longitudinal.—In the direction of the length of an object, or generally that of its longest dimension. It is prefixed to such views on drawings, as "longitudinal elevation" or section, sometimes termed a front, or a side view, or section. Longitudinal seams are the joints in a boiler which run parallel with the axis.

Long-Toothed Gauge.—A marking gauge used by pattern-makers, having the marker adjustable for length in its stem, which stem is also adjustable in the body. It is therefore able to scribe lines at various heights,

or in planes which could not be reached by the common gauge.

Looping Mill, or Belgian Wire Mill.—A rolling mill used for the production of rods. It derives its name from the bending or looping of the rods backwards and forwards between successive rolls, instead of waiting until a rod is reduced along its entire length before passing it into the next set of rolls. It is a method only suitable for small rods, or those of not over $\frac{3}{4}$ inch diameter, which can be turned back by the catcher. But within these limits the economies effected are enormous. Small rods, if rolled by ordinary methods, get cold so soon that they cannot be produced in great lengths such as for telegraphic wires. But if looped they leave the rolls at about as high a temperature as they enter them.

In this system the stands of rolls are arranged end to end, coupled up together. The bar in its first pass, coming out between the bottom and the middle roll is seized by the catcher, and bent and returned for the next pass between the middle and top roll, where another catcher takes it, and passes it through the next pair of rolls, and so on. The bar may be looped thus six or eight times.

A little consideration will show that the action of rolls coupled up thus, and therefore all running at the same speed, does not correspond with the speeds of the rod which is being reduced. As a rod passes away from the rolls it acquires a higher speed than that at which it entered, and corresponding with its increased length due to reduction. Entering rolls all running at uniform speeds, the loops therefore become lengthened, and are a source of danger to the men. Improvements have been effected in making successive rolls of larger diameters, and running them at increasing speeds, and in winding the rods on a reel as they leave the final pass. But the looping system has been subject to many modifications in modern designs.

Loose.—A common prefix applied in several cases. Loose centres are machine, or planer centres. A loose coupling is any coupling or clutch which can be connected or disconnected while running. A loose eccentric is an adjustable eccentric, formerly, and still used in the absence of link reversing gear. See also terms below.

Loose Gland.—A term sometimes applied to the loose flange or ring used in making joints in hot-water piping. The ring, having lugs and bolt holes, is slipped over the socketed end of one pipe, an indiarubber ring placed in front, and the spigot end slid into the socket of its fellow pipe, also having lugs and bolt holes, which on being tightened up to the ring makes a secure joint while allowing expansion to take place.

Loosening.—*See* **Rapping.**

Loosening Bar.—A rapping bar.

Loose Pieces.—Portions of patterns, which, occurring on the sides of main portions, would prevent the withdrawal of the latter from the sand if rigidly fixed thereto. Being loosely attached, they are left behind in the mould, and taken out therefrom subsequently to the main portions, entering then into the spaces left by their withdrawal. This is a general statement only, which takes no account of numerous modifying conditions.

The methods by which loose pieces are retained during ramming are generally skewers, loose nails, dovetails, or dowells. The choice of either varies with circumstances. In any case the object is to prevent the loose piece from becoming shifted during ramming, while ensuring that at the time of withdrawal it shall be entirely detached from the main body.

The simplest method of securing pieces temporarily is by wire nails thrust loosely into holes, and standing out by about an inch. When sufficient sand has been rammed round a piece to prevent its dislodgment, the nails are withdrawn with pincers, and the ramming then completed. A better plan is to use skewers or wires, which having an eye turned on the outer end can be withdrawn by the fingers (Fig. 161, A, at *a*).

Dovetails are only suitable in some situations; they can only be used along the bottom edge of a pattern, because elsewhere the projections of the dovetails would interfere with withdrawal. They are not used for odd jobs, but only for standard work, because they take more time in fitting than the skewers do. They might be

adopted alternatively to the skewers in A. They are indicated in E.

As loose pieces have to be withdrawn into sand spaces, they must be smaller than those spaces, as at B. Often they are larger, and when that is the case, the pieces must be divided. Thus if a strip, say 2 inches wide, has to be withdrawn into the space left by a rib 1 inch thick as at C, it must be divided into three, *a*, each thickness to be withdrawn in succession. But generally when the thickness involves more than one division another course is adopted, because of the difficulty of inserting a pricker and getting the pieces out. Thus the pricker seen in B could not be used for withdrawing the inner thickness, as in C and D. Sometimes the cleaner is used to draw such a piece towards the rib. But then mending up is generally required, and that is difficult. Hence such loose pieces should be avoided. Instead, an interior body of sand may be lifted on a core plate, such a plate being indicated at *a* in the diagram E, leaving ample space for withdrawing loose pieces into. Or if that is impracticable, the outer sand containing the loose pieces is lifted away on drawbacks as at F, *a*, *a*; this also affords an illustration of the use of dowells. Or the interior may be cored, G. As it is obviously unwise to have loose pieces so broad that the cleaner cannot be got into them for mending up or smoothing, this, apart from the difficulty of withdrawal piecemeal, limits the breadth to be drawn into narrow vertical spaces, and renders the adoption of other methods necessary. It is also clear that loose pieces must have ample draught in order to allow of their being withdrawn with a pricker inserted from above, and often without the possibility of loosening them by rapping.

There is another class of loose pieces left loose for another reason, namely, deep pieces in the top of the mould. This is done because there is far less risk of the mould becoming fractured when the pieces come up in it, and are withdrawn afterwards, than when the mould is pulled away from them. All deep ribs H, and bosses J, which are surrounded with sand, are left loose for this reason. In these cases dowells or studs are used, fitting loosely in the pattern body, and tightly in the loose piece.

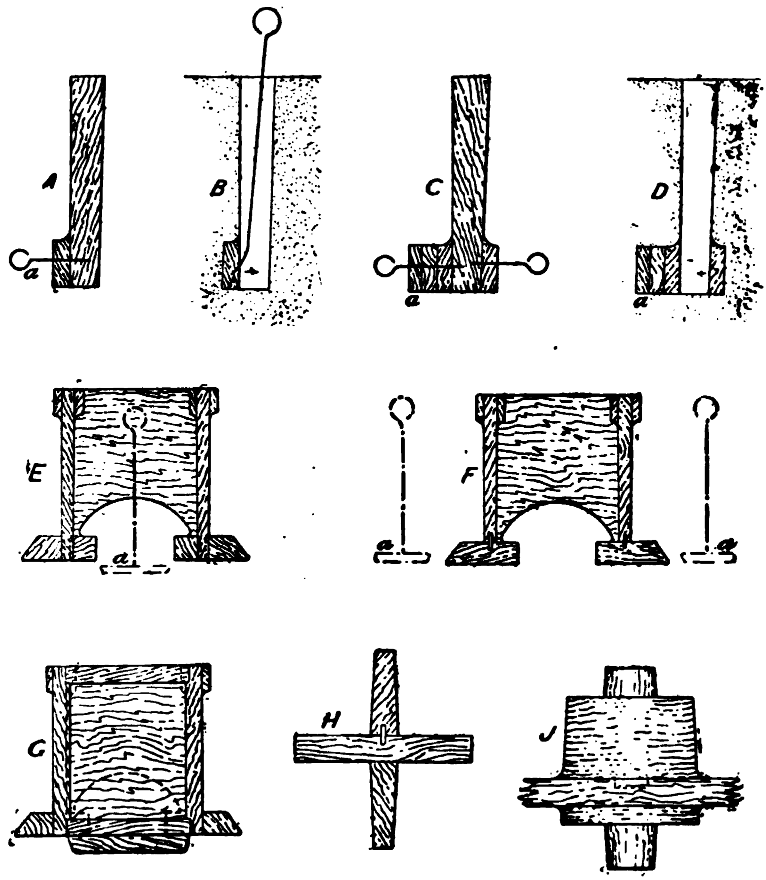


Fig. 161.—Loose Pieces.

Loose Pulley.—*See* **Fast Pulley.**

Lorry.—A low type of truck.

Loss.—It is an axiom in mechanics that there is no loss in mechanical exchanges, but that energy suppressed in one direction reappears in another. But it is necessary to apply the term to the difference between theoretical and actual results, or to the work absorbed by a motor or machine. The term is also applied to the waste of metal in furnaces of various kinds.

Loss—Electrical.—The losses in generating and transmitting electricity are small compared with other sources of power. *See* **Electric Driving**.

The electrical losses in a dynamo consist of the hysteresis loss (*see* **Hysteresis**), eddy current loss, and the loss caused by having to force the magnetising current through the resistance of the field windings; but these are so small that generators are now constructed in which, including the losses due to bearing friction, windage and all other leakage, the inefficiency loss is not more than 5 per cent. of the power applied to their shafts. Motors, and especially when direct-coupled to the machinery to be driven, will give a commercial efficiency of 86 to 90 per cent., even in small sizes, such as 10, 6, or 5 B.H.P.

Electrical losses occur in transmission by cables, but can be reduced to an economical point by proper selection of conductors. *See* **Electric Cables**.

Thus by skilful design of apparatus, electrical loss in generation and application of power can be rendered so small as to eliminate competition by any other method of producing, transmitting, and using power.

Lost Motion.—The difference between the speed of driving and driven elements, due to slip of some kind.

Lost Pass.—The return passage of a bar or rail over a two-high mill, which has no reversing motion.

Low Breast Wheel.—*See* **Water Wheels**.

Low-Pressure Cylinder.—*See* **Compound Engine**.

Low Pressures.—*See* **High Pressures**.

Low Red Heat.—Corresponds with a temperature at which the red colour is fading into a black. It is a dangerous heat at which to do work on iron and steel, producing a condition of brittleness which can only be counteracted by annealing. Light work done at this heat may have no ill effect. Thus, the smoothing of the surfaces of forgings by the battering off of the smith is common. Specifically, the evils of doing severe work at a low red heat have reference to the thinning of the edges of boiler plates, bending, and flanging, and work of a similar kind.

Low Water Alarm.—A device by which, when water falls dangerously low in a steam boiler, a whistle is made to blow. It consists essentially of a float, the fall of which with the water, opens the steam passage to the whistle. The action is either direct, or a chain with a counterbalance passes over a pulley.

L-Rest.—A lathe rest in the form of the letter **L**. It is used by metal turners employing hand tools. It is stiff and does not stand out in the way like the tee rest.

Lubricants.—The object of lubrication is to interpose something between metallic or other surfaces which shall prevent them from coming into actual contact. No matter how thin the film of lubricant is; that, so long as it remains efficient, is what it does. Squeeze out the lubricant, and the surfaces coming into contact, set up friction. It is clear that a film of lubricant must be subject to the same pressure as that of the bodies in contact. Also, that a lubricant having a sensible thickness substitutes rolling friction for that of rubbing. In fact the analogy is perfect between ball bearings and lubricants, for the latter may be regarded as composed of an almost infinite number of minute balls. The particles of the lubricant move between the bearing and shaft.

The choice of a suitable lubricant depends on circumstances. A thick oil, and a thick film of oil are better than thin from the point of view of durability. Though a thin oil gives less friction, it does not last. Hence an oil with a good *body* is desirable. But the question of high temperatures here comes in, since many thick oils become thin at high temperatures. A thick oil is not better in itself than a thin one, but being less easily squeezed out, it is more durable, and from that point of view preferable. The best results are obtained by a judicious mixture of thick and thin oils—*compound oils*, in which the thin oil corrects the

viscosity of the thick, so enabling the particles of the latter to roll freely. The case is on a parallel with the ball bearing, in which the balls need lubricating, the analogy between the heavy and light oils corresponding with that between the balls and their lubricant. Thus, sperm and mineral oils in equal parts give better results than sperm alone. An oil liable to gum may be mixed with advantage with a mineral oil.

To test the value of a lubricant, or its *coefficient of friction*, is the purpose of oil-testing machines. But they do not tell anything about properties besides the viscosity of the oil, nor give any hint of the varying conditions which exist in different classes of machines. It will often happen that endurance under great pressure is of far greater virtue than the use of a lubricant which shows a degree of friction several times less at the testing machine. A thick grease is more economical for heavy duty than a thin oil like lard, or sperm, notwithstanding that it results in greater friction, because the grease does not become squeezed out and run away so readily, nor is it used in such large quantities as the thin oils.

Though the function of a lubricant is to interpose itself between metallic surfaces, and so prevent their contact, and take the same pressure which exists between them, yet the thickness of the film may be extremely attenuated. This is most strikingly shown in the experiment of thrusting a plug gauge into a ring gauge dry, and with oil. With a pair of finely fitting standard gauges, differing by about a thirty-thousandth part of an inch in diameter, and having dry surfaces, the plug can only be thrust with difficulty into the ring, and if suffered to remain there for an instant or two, it cannot be withdrawn without the exercise of force, which may tear up the surfaces. But, rubbing a little oil on with the finger, the plug can be readily inserted, and moved about. Yet if allowed to remain for a short time, the oil becomes squeezed out, and seizing occurs. This shows that an extremely thin film of oil is efficient, and also that the time of retention of the oil is of much importance.

Another point is that the conditions which are most favourable to the use of a thin oil, namely, highly polished surfaces in contact, do not exist in the journals of large engines, mill rolls, shafting, and much else until they have become worn, and not always then. The smoother the surfaces in contact the thinner the oil which may be used. In fact, water would be a suitable lubricant from this point of view, but it would lack durability. Water is used in the submerged bearings of many turbines.

The value of end play between journals and bearings is considerable from the point of view of lubrication. It prevents the formation of grooves, the presence of which increases friction, and requires more lubricant than surfaces destitute of grooves. With regard to this point, Professor Denton has given a minimum of 5 per cent. lost in friction with bearings such as those of shafts, against from a fraction of 1 per cent. to $1\frac{1}{2}$ per cent. in railroad bearings.

Returning to the plug and ring; if a thick, heavy oil is used, the plug can still be pushed into the ring, but greater force will be required, and the plug and ring may remain in contact for a longer period before they will stick. These facts illustrate the property of viscosity. It is to determine problems of this kind that the **Oil-Testing Machines** are employed. But in estimating the value of an oil, the results obtained at the testing machine must be supplemented by considerations of the conditions under which the lubricant has to be used.

The leading characteristics of oils are viscosity, flashing points, acidity. The oils are classified as animal, vegetable, mineral, and compound.

Viscosity.—This is related to temperature, because as temperature increases an oil becomes less viscous. Its determination is best effected by the use of a glass tube set vertically, drawn to a small hole below, and enclosed in an outer cylinder, which is filled with water of the temperature at which it is desired to make the experiment. The hole being closed with the finger, the lubricant is poured in to a definite height, and the oil is allowed to flow out. The rapidity, or slowness of the flow of various oils is a measure of their relative viscosity. Comparisons must be made at different temperatures, because the thicker animal oils contain much stearine, which is sensitive to increase in temperature, and these are better,

being more durable where there are high temperatures than the thinner oils. The following table by Allen shows the relative viscosity of various lubricants at three different temperatures, in the number of seconds required to empty a given tube :—

Kind of Oil.	Number of Seconds required.		
	At 60° F.	At 120° F.	At 180° F.
Sperm Oil - -	47	30½	25¾
Olive Oil - -	92	37¾	28¼
Lard Oil - -	96	38	28½
Rape Oil - -	108	41¼	30
Neats' foot Oil -	112	40¼	29¼
Tallow Oil - -	143	37	25
Engine Tallow -	Solid	41	26½

The pressure upon the bearings has to be taken into consideration also; a thin oil, though suitable for light running machinery, is not suitable for heavy. On the other hand a thick oil requires greater driving power. This, however, though a matter of importance when driving power is small, is of no consequence when the power is so far in excess that the resistance of such a lubricant is a mere trifle, as for example in rolling mill machinery.

Flashing Point.—This relates to the mineral oils. These are obtained by the distillation of rosin, shale, and petroleum. They are not definite bodies like the fixed oils of animal and vegetable origin, but complex mixtures of hydrocarbon oils, giving all kinds of characteristics. The flash points, or the temperatures at which inflammable vapours are given off, range from 270° Fahr. to 450° Fahr. For gas engines and steam cylinders the flashing point should not be lower than 400° Fahr., while generally a low flash point involves risk from fire.

Acidity.—The animal and vegetable oils are liable to develop fatty acids, an evil from which the hydrocarbons are free. They are converted into soaps by the presence of alkalies. Saponification consists in the reaction of a fixed oil with the elements of water, with the formation of a fatty acid, and glycerine, or allied body, producing oleic and stearic acids. The action is caused by superheated steam, hence the objection to the use of fixed oils for engine cylinders, and the substitution of the mineral oils in such conditions.

Cylinder Oils.—These include *distilled oils*, produced by distillation and chemical treatment from petroleum. *Natural oils*, being dark opaque oils of great body, prepared by settling at high temperatures, filtration, and exposure to superheated steam. *Filtered oils*, prepared from the natural oils, by filtration at high temperatures through animal charcoal. The natural oils are for most purposes to be preferred, and when filtered through animal charcoal. They have more body than those used for shafting and other bearings. They must also have high flash points, and good viscosity.

Cylinder oils are the products of distillation, repeated, in which the benzines and burning oils are removed. Steam is let in at a certain pressure and temperature, leaving in a first stage a dark and cheap steam-refined cylinder oil. With each successive refinement the cost goes up, the temperature is increased, and the flash point rises. The cheaper qualities, after being allowed to settle, are sold then in barrels. The better qualities are strained, and then filtered to extract the water and other foreign matters, and allowed to settle. The filtering is done to render the oils pale. It is done through bone-black. The value of a cylinder oil depends on its friction-reducing qualities in the presence of steam, wet, or superheated. Various conditions are demanded, relating to sp. gr., flash point, viscosity at a certain temperature, or by reference to another oil as standard. Freedom from acid, wax, fatty matter, and light hydrocarbons is specified, and a minimum rate of evaporation at a high temperature for a number of hours. The experiments of Mr H. M. Wells have shown that the viscosity test is of no value when cylinder oils are in question, for at 500° Fahr. all oils tested were about on a level. Also, that in all, the vaporising temperature is much below the flash point, so that the oil must be heated in most cases at least 150° Fahr. above its vaporising temperature. Also, it was demonstrated that the usual evaporating test is no index of quality. The conclusion is inevitable that no one oil exists for all types of engines and valves.

That the physical tests of the laboratories do not give any indication of the behaviour of oils under steam, heat, and pressure, and that they are therefore of no practical value.

The following table of standard oils by J. Veitch Wilson is of interest:—

Properties.	Solid Tallow.	Castor Oil.	Refined Rape Oil.	Cylinder Oils.		Machine Oils.	
				Filtered.	Natural.	Refined.	Natural.
Specific gravity at 60° Fahr.	943	963	916	889	900	910	883
Specific gravity at 120° Fahr.	886	941	896	865	876	886	859
Viscosity at 180° Fahr.	100	231	106	341	413	106	104
Viscosity at 280° Fahr.	65	82	68	97	106	59	62
Viscosity at 360° Fahr.	55	60	58	70	70	50	52
Flash point (open test)	480	510	508	545	556	400	370
Loss per cent. on exposure for five hours to 360° Fahr.	0·38	0·73	0·79	0·02	Nil.	2·34	5·73

Steam pressure of about 160 lb. per square inch.

Adulteration.—The expensive oils are often adulterated with cheaper ones, which can only be detected by the chemist, and then often with difficulty. Some of the principal adulterants are the following:—Olive oil is mixed with cotton seed oil, colza oil, peanut oil, and poppy oil. Lard oil is adulterated with palm-nut and cocoa-nut oil, with fish oils, and cotton seed oils.

Solid Lubricants.—Graphite is the best lubricant for the high temperatures of superheated steam, being unaffected by temperatures that partially or wholly vaporise ordinary oils. It fills up pitted cavities, or coarse-grained metal, and leaves a glossy surface, and remains a permanent protective coating with a glass-like surface. It may be applied in flakes, or mixed with water, or vaseline, or oil.

Rust.—Rust is a great enemy to lubrication, because it destroys the smooth metallic surfaces. All parts liable to rust should during lengthy periods of disuse have attention, by taking means to prevent the formation. Surfaces should be oiled or greased, and access of air and moisture prevented as far as possible.

Lubrication.—This subject is much better understood now than formerly. The old slowly-moving engines, shafts, and spindles caused little trouble. But difficulties arose with the advent of high-speed engines for torpedo boats and dynamos, and with main line shafts, and countershafts, the spindles of grinding machines, &c. Long before the general engineers had been compelled to give much study to this subject the locomotive engineers had solved the problem for themselves in a practical way, which later experiments have shown to be absolutely correct. That is, by introducing the lubricant from below to the sides of the bearing, and leaving lateral play between the journal and its bearing.

The experiments of Mr Beauchamp Tower (1883 and 1885) demonstrated that the proper way to lubricate a bearing is not from the top, as has been the most common practice, but from the bottom. To feed from a gravity lubricator through a centre hole was the worst possible method. The best was that which permitted the lower side of the journal to run in a bath of oil. Lubricating from above, the oil does not enter, or if it is caused to enter, it is squeezed out again, and forced up through the hole. The cutting of oil grooves was helpful with light loads, but failed under heavy ones. Using a bath, the lubrication was more than six times as efficient under a similar load. From these and other experiments it was found that the proper way to lubricate is to bring the oil in at the side or edge of the bearing or brass, where there is no pressure, and let it be carried round to the top, where the pressure is often greatest. Also that an oil bath which keeps bearing and journal always wet, is much better than a pad, which supplies a film hardly perceptible.

But the condition under which these experiments were made was that of constant thrust.

When, however, the journal is eased from absolute contact with top and bottom brasses alternately, spaces are left into which the oil insinuates itself. So that as there is never absolutely close contact between journals and their bearings, experimental conditions are not present, and top gravity lubrication often answers tolerably well. Nevertheless the system is not suitable for the conditions of high-speed practice, in which the oil bath device has grown with great rapidity. The gravitation method does not supply sufficient oil, it does not bring it in at the locations of least pressure, and it is not capable of regulation. Its efficiency depends on some slackness in fitting, which is a variable quantity. Although in most brasses oil grooves are cut to distribute the oil from the top to the sides, or to the location of least pressure, that is a device which, though valuable, has not so good an effect as commencing to lubricate at the sides. Mr Dewrance has designed bearings in which the oil is led in at the sides, through grooves to the top, but with no hole at the top through which oil can escape.

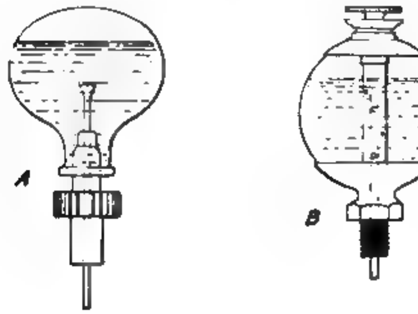


Fig. 162.—Lubricators.

For high speeds the methods of lubrication include the oil bath, using a splash system; or forced lubrication, and automatic mechanical lubrication. The oil bath and the forced, or pressure system are often combined (*see* **High-Speed Engines**). Mechanical lubrication relates to the methods of supply itself, without reference to the design of the bearing.

With reference to the practice of using the same oil over and over again, it is believed that it becomes "worn out" in time. But this is doubtless due to oxidation. If this does not occur there seems no reason why the same oil should not be used for a long while, provided it is properly filtered, and allowed to settle to remove the dirt and metallic particles which become mixed with the oil. The advantage of this practice is that abundant lubrication can be done, whereas when oil runs to waste there is a strong inducement to use as little as possible, to the detriment of the machinery. Also a good oil can be used, which is more economical than a poor one.

Lubrication, when efficient, is an important aid to cutting metals. Even using the same tools, the difference in an insufficient and a full supply, or between a suitable and unsuitable lubricant, may easily make from fifty to a hundred per cent. difference in the weight of cuttings removed. The automatics in which forced lubrication is often used, have taught the lathe man valuable lessons in this respect, which have not yet been as fully utilised as they might be in the practice of the general lathe hand.

Good lubrication is much assisted, and its expense lessened, by all the devices which are in use for reducing friction between surfaces; such as anti-friction materials, good fitting of parts, as well as the selection of lubricants

suitable for the particular duty imposed on them. The excellent results of using hard or good mottled, close-grained iron for cylinders and cylinder liners is familiar, as is its application in the bearings and journal necks of large headstocks. For the same reason steel and iron are run against the bronzes and brasses.

Lubricators.—The vessels by means of which oil or tallow are conveyed into the bearings of shafts and sliding parts. The simplest are of gravity type, others depend for their action on the principle of the syphon, or on capillary action, others on a splash, on a licking or picking up of the oil, or on pressure obtained from a pump. The operation may be invisible or open to inspection, and capable of regulation or not. It may be a single tube supply, or multiple tube system.

Gravity Lubricators.—The most crude kind is the old oil cup used largely on plummer blocks and on the slide bars of cheap engines. Oil was simply poured in at intervals when the parts began to feel warm. The cup form of lubricator is derived from this, in which a grease or oil cup, open or closed, is fitted with a tap to permit of regulation of the supply to the bearings. The open kind or "cup" has but one cock; the closed or "globe barrel" form has two, one for filling the globe through, the other for supplying the bearing. These types are used more on steam engines than elsewhere, for lubricating the pistons and slide-valves.

Syphon Lubricators.—These are often combined with an oil cup. The oil surrounds the central feed tube, it is drawn up and down into the tube by a cotton wick acting as a syphon, the larger portion going down into the oil supply hole. Capillary action takes place slowly between the oil and the fibres of the wick.

Needle Lubricators.—The Lieuvain lubricator, used mostly for plummer blocks, provides a constant supply which ceases when the shaft is not rotating. A glass vessel above holds the oil, Fig. 162, A, B. Its neck is closed with a plug through which a needle projects, one end of which rests on the journal, the other end passing within the reservoir. Under the vibration of the journal the oil is fed down slowly. But when the shaft ceases to rotate the oil does not pass beyond the neck.

Stauffer's Lubricator.—This is one which holds solid lubricant. It is fitted with a screw cap, Fig. 162, C, which being turned round at intervals exercises pressure on the lubricant, and prevents the upward pressure from forcing the lubricant away from the surfaces, which often occurs when oil is used in the common plummer blocks. A rise in temperature melts the lubricant. The spring inside the cap prevents the latter from becoming loosened through vibration. An improved form, D, has a spring-actuated plunger in an extension at the top, which maintains an automatic feed on the grease after the cap has been screwed down. A slight turn of the cap forces this plunger up again; the shank projecting at the top indicates the condition of the feed at a glance. The slotted screw in the shank allows the feed to be regulated; it cannot be tampered with after the cup is closed. Another grease lubricator feeding by spring pressure is shown at E. The feed is controlled by the transverse set-screw in

Fig. 163.—Roscoe's Lubricator.

the shank. This simple method of forced lubrication renders the design of service in awkward situations where the attendant is only able to approach bearings at intervals.

Roscoe's lubricator depends on the action of condensed steam. In Fig. 163 the inside of the body A is fitted with a tube, B. Steam comes through the passage at C, which may be closed by the screw plug, and condensing, falls to the bottom, forcing out some of the lubricant

Fig. 164. -Mollerup Lubricator.

above it, through passage C, and causing it to mingle with the steam going to the cylinder and parts. The cap D is given a part turn to uncover a hole in the top, the plug E being unscrewed to let fresh lubricant fall into the chamber A. The plug F is opened when re-charging to let the condensed steam run away.

Splash Lubrication.—This relates to the use of enclosed spaces, specifically those of the high-speed engines in which the ends of connecting rods dip into a bath of oil and splash it up over bearings. It is a case of partial or complete immersion once in each revolution. Another kind is that of a licker which dips at each revolution into an oil bath, and throws a single drop of oil on a bearing which is not in contact with the bath. These devices are only suitable under conditions which are very limited in scope.

Oil Bath Lubrication.—This includes the splash device, and forced lubrication, but it embraces the kind in which the journals y run in a bath of oil. This may partly ɔmpletely fill the chamber, generally the er. In that case the oil is borne upwards ne rotation of the shaft, the lower side nich runs in the bath. Or, the *ring oiling* e is used. In this case the journal has ɔove turned, within which a very loosely g ring drops. It is immersed in the oil , and is carried round by the journal so ging up a supply of oil with it. A chain ten used instead of a solid ring.

rced Lubrication. — This signifies that h is produced by the action of a pump, h is generally of centrifugal type to proa continual flow. Or a valveless pump is enclosed in an oil bath, as in some high-speed engines. The advantages are great; the lubrication is constant and reliable, and economical, because the same lubricant is used over and over again. sure is varied with requirements from a very t quantity to 20 lb. to the inch. Forced ication is largely used for another purpose, of keeping cutting tools and their work cool, so increasing their efficiency.

The Mollerup force-feed or mechanical plunger lubricator, Fig. 164, derives its action from some reciprocating portion of the engine, connected with a rod to the adjustable clamp A on a pivoted rod which has a spring pawl working into teeth on the ratchet wheel B. Each stroke gives a partial turn to a worm on the spindle of B, rotating a worm-wheel C, which turns a screw that gradually pushes down the piston D, and forces lubricant out of the cylinder E, and thence through the horizontal tube to the various parts of the engine. The cup F holds a supply of oil, which is drawn into the cylinder

E by turning the cock below F to make the passages communicate, and raising the piston D rapidly by the handle above C, coupled to it by a friction bolt device. A friction pawl is often fitted instead of the ratchet at B.

Sight-feed Lubrication.—Also termed *visible-drop feed* lubrication, depends for its action on

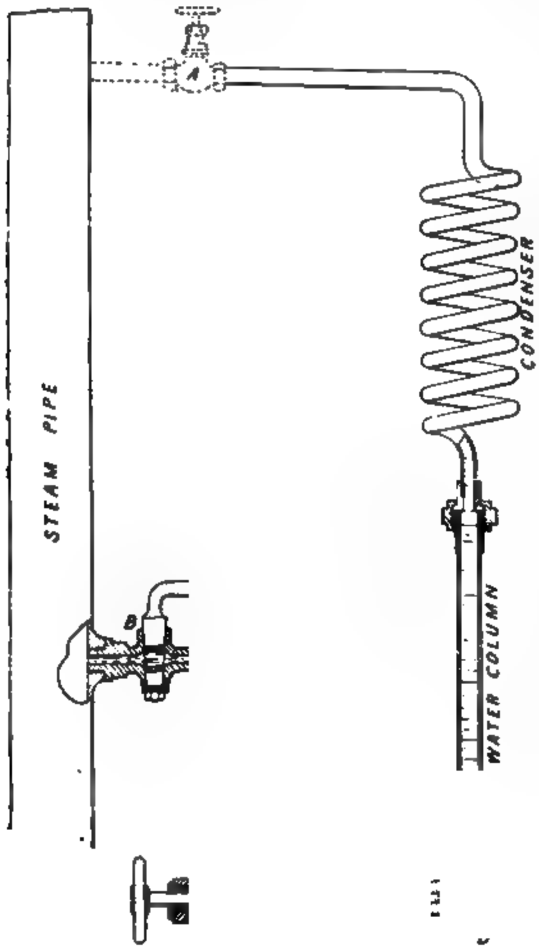


Fig. 165.—Sight-feed Lubricator. (Smith's Injector Co. Ltd.)

the regulation of the supply of oil, in conjunction with a glass tube containing water, through which the escape of the drop of oil can be seen. It occurs in many patterns. Fig. 165 shows one in which the action of steam coming through the valve A has the effect of forcing oil out through the cock B, and so turning the steam in the pipe into greasy steam. The *condenser* cools the steam, and it falls as water down the column, forming a head, which then passes along and up into the cup C, forcing out the oil therein, through the valve E, and up the glass G, where the drops are visible. The valves A, D, and E are closed while the cup is being refilled; E may be adjusted to regulate the supply of oil. A drain-cock is placed at F to carry away the water at refilling.

When bearings of engines and machines are inaccessible during the period of running, several oil tubes are generally supplied from a common oil box, and these are often of the sight-feed and regulating type. There are several improved designs of these boxes.

Luffing. — Identical with derricking, or altering the radius of a pivoted job.

Lumber.—As used in America, is the equivalent of the English word timber, irrespective of whether balks or planks are denoted.

Lustre.—The property by virtue of which surfaces reflect a proportion of the luminous rays which fall upon them. Metallic surfaces reflect light in proportion to their hardness, if similar conditions of smoothness of surface or polish are present.

A polished surface reflects more lustre than a roughened surface, because the light rays which are broken and dispersed in all directions from the latter are nearly all reflected back to the eye of the observer in the former. Lustre is 'iminished when a surface becomes broken by xidation, the film of oxide formed being destitute of lustre.

Lute, Luting.—A joint made between a cover and a vessel containing substances or articles to be raised to a high temperature in a furnace. The object of the lute is to exclude the air. Fire-clay is employed because of its capacity to resist the heat.

Lyddite.—Is a powerful explosive, taking its name from Lydd in Kent, where it was first tested at the Government artillery range. It consists of picric acid, $C_6H_2(NO_2)_3OH$, which is produced by the action of nitric acid on phenol or carbolic acid, 1, 2, or 3 atoms of hydrogen being substituted by NO_2. It is a brilliant yellow crystalline substance with a very bitter taste.

M

Machine.—A combination of elements, the relative motions of which are under constraint. A simple element cannot constitute a machine. Thus, a lever arm apart from its fulcrum, or a wheel apart from its shaft cannot be a mechanism, or a machine. The links, or kinematic links of a closed chain are not machines, though the closed chain is. Constraint is also an essential, in order that exact relative motion may take place. This constraint can only occur when the elements are connected in pairs, and when one link is fixed. *See* **Closed Chains**.

A machine, in the common acceptation of the term, is a combination of constrained links, forming sliding, and turning pairs. The framings, shafts, and massive castings and forgings used in construction may be neglected in tracing out the elementary pairs, as they are not concerned with the essential motions, but only with questions of strength and stability.

Machine Centres.—A pair of point centres carried in headstocks and bolted down to the table of a planer, shaper, slotter, or miller for supporting circular or partly circular work by countersunk holes in the ends. The plainest centres comprise simply a tailstock with fixed centre, and a headstock with a hand-wheel and screw for tightening up the centre. The work is further blocked up, if necessary, by packing pieces, or screwjacks underneath to prevent rotation, or possible bending down under the pressure of the tools. When it is necessary to set the work in successive circular subdivisions, the plain centres are not applicable, unless the work is marked out beforehand; to avoid this, **Index Centres** are employed.

Machine Framings. — These have gone through great developments. The early framings were of light design, mere skeletons, generally plain ribbed castings. Heavy cutting, if attempted, caused vibration and chatter. A great advance was made when the box type was introduced. The same amount of metal if used in a hollow casting instead of in a plated and ribbed one produces much greater rigidity and strength. It would be interesting to trace how this idea has been embodied in successive machine types. It may be observed in the drilling machines, planer housings, slotting machines, milling machines, punching and shearing machines, and later in some of the lathe beds. At the same time the abrupt angles formerly so prevalent have given place to curving and flowing outlines and large radii, and to broad spreading bases which conduce to stability, as in the vertical types of machines. The cabinet legs are but an extension of the design, taking the place of ribbed legs, and being enlarged and fitted with shelves to form cupboards.

Machine Gun.—An automatic gun which fires a large number of shot or shell in a short space of time. The Maxim was the first automatic field gun used in Europe. But guns of far greater power are now automatic. Messrs Vickers, Sons, & Maxim, Ltd., have the "Pom-pom," a 37 mm. gun; and 3-pounder, 6-pounder, and 14-pounder guns, the latter chiefly for naval service. Guns of different calibre now fire in a minute three hundred 1-pounder projectiles, thirty-five 3-lb. shots, thirty 6-pounders, and twenty-five 14-pounders, ranging in velocity from 1,800 ft. to 2,500 ft. per second. The Maxim will fire 800 rounds per minute. The essential principle of these guns is the utilisation of the recoil after discharge for the preparations for the next discharge. The discharge withdraws the cartridge, and another is passed into the chamber. The operation continues of withdrawing shot from a belt, loading, firing, and ejecting the cartridge case.

In the Pom-pom the rate of fire is from 250 to 300 rounds per minute. Each shell, weighing about $1\frac{1}{4}$ lb., bursts on impact into about a

dozen pieces. It is impossible to stand against the hail of such guns.

The interchangeable system is adopted in the manufacture of these guns. In a Maxim gun there are about 280 parts thus made. Drop forging is adopted for the forgings, followed by pickling. Milling is largely done, some of the parts requiring twenty-seven different operations, each one of which is gauged. About 550 distinct operations are carried out on the parts of a Maxim gun. 400 parts go to the making of a Pom-pom.

Machine-Moulding.—The general advantages resulting from the use of moulding machines are briefly:—A perfect lift truly vertical, without unsteady movements such as occur in hand lifting, producing broken moulds, and to prevent or lessen which, more taper—in itself generally objectionable—has to be imparted to patterns delivered by hand than by those drawn by a machine. One result which follows is, that allowances for tooling can be reduced when castings are machine-moulded, because they come out more nearly to dimensions, and have less taper than hand-made castings do. In some cases machining may be dispensed with, and black fits substituted. Or grinding may take the place of machining. Also the making of sand joints by the pattern plate instead of by the hands is an advantage. And generally the moulding of the runners from the plate, instead of cutting them for each separate mould. In every hand-made mould, not plate moulded, the first joint face has to be made by the hand and trowel of the moulder, working from the joint edges of the pattern to the joint of the box. When such joints are not plain they often occupy a considerable time in making. In a moulding machine, the joint face, however awkwardly shaped, already exists on the pattern plate. So also when runners occur, singly, or in numbers, they are provided on the plate.

The preparation of patterns for machine moulding varies. It is derived from the practice of plating patterns, to avoid the labour of preparing joints afresh for every mould. Having pattern parts attached to a plate of wood or metal, it is easy to fix that in a machine, ram by hand, and use the machine for withdrawing the pattern parts from the sand, or the mould parts from the pattern, either method being commonly practised.

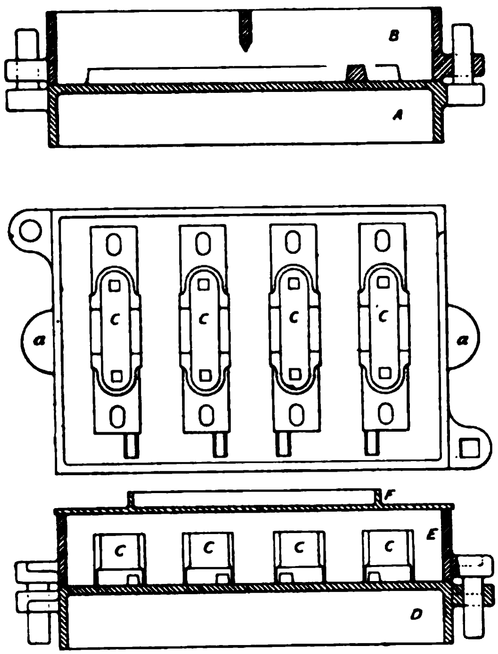
The mounting of metal patterns on metal plates, and the fitting of runners thereon is one stage in plate and machine moulding. An advanced stage is that in which pattern parts for top and bottom are mounted on separate plates, to be moulded on the same, or on different machines. Ordinary shallow patterns, and those which have sloping sides, or are of semicircular form, deliver readily. But deep patterns with no taper do not, hence the stripping plate is designed to encircle such patterns closely, and hold down the sand during the withdrawal of the pattern.

With regard to the different classes of work done on machines, these now embrace a much wider range than they formerly did. In the smaller articles they score best, and their utilities were for many years chiefly confined to these. Now, however, patterns of several feet in length or diameter are moulded by machine.

The best examples of small patterns are afforded by the practice of the brass moulder, where a dozen or more are often mounted on a single plate; parts being on opposite sides of a single plate, or on one side of two separate plates. These do not require large machines. But if machines larger than are necessary for these are laid down, there is the advantage that two groups of small patterns can be moulded at one time, which may include a top and bottom part. Or a larger pattern or group of patterns can be put on.

Most machines are of the general kind, suitable for taking miscellaneous work. But some are built for special duties, taking one kind, or size of pattern only, of oblong or circular shape; as, say, radiator castings, or belt pulleys, plain plated work, or gear wheels.

In the most advanced developments of machine moulding, conveying systems are installed to bring materials and boxes to the moulders, and to take the moulds away for casting. In the majority of cases these are simply rails which run along under the machine, and are continued on each side of it. In others circular tracks are provided.



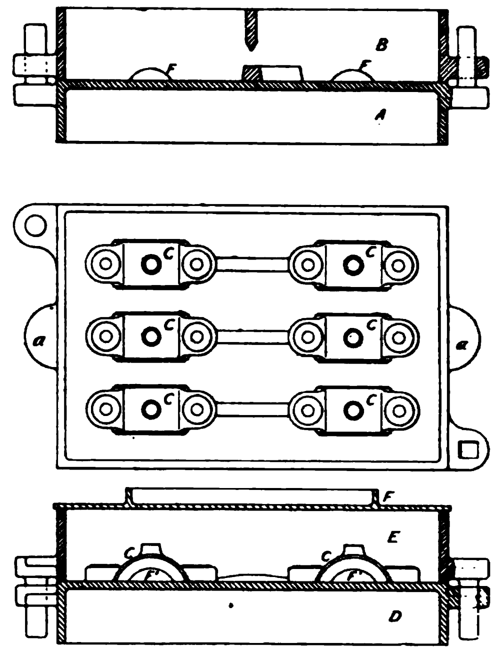


Fig. 166. Fig. 167.

Patterns and Boxes. (Darling & Sellers, Ltd.)

Snap flasks are used largely in machine moulding, the flasks being removed from the moulds after ramming, and the latter laid upon the floor and weighted for casting.

Not the least of the advantages derived from machine moulding is that the attendant stands at his work, instead of kneeling on the floor.

A pair of pattern boxes prepared for use on the moulding machines made by Darling & Sellers, Ltd., are shown in Figs. 166, 167. They are fitted up for moulding pedestals and their caps.

Two sets of boxes are used for the top and bottom moulds, so that each set can be made on separate machines, or a number of tops and then a number of bottoms on one machine. Fig. 166 shows the work for the pedestals. The upper figure is a longitudinal section through the pattern box A for the top, and its moulding box B. As the pedestal moulds are contained wholly in the bottom, the top is a "plain top," and contains only the runners. These are mounted on the face of the pattern box A, the

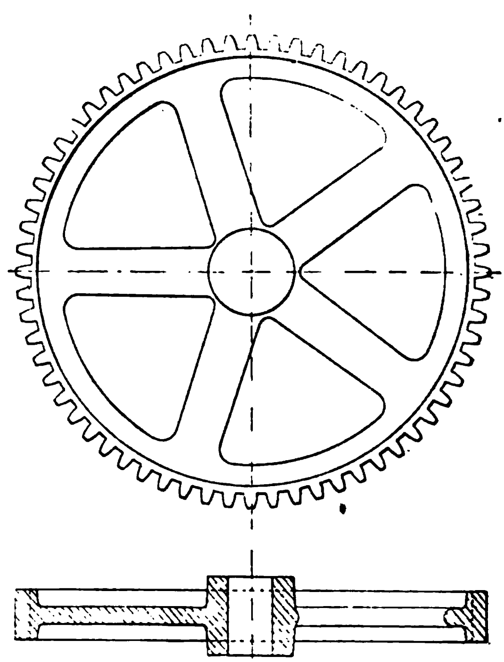


Fig. 168.—Pattern to be Moulded.

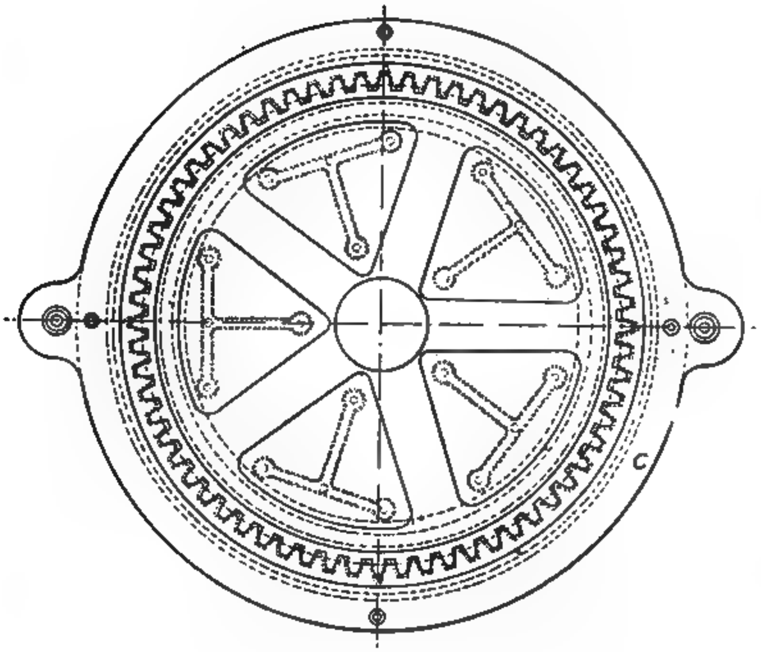


Fig. 169.—Pattern Arrangements for Bottom Part of Mould.

lettered similarly. The bearing concavities of the caps are represented by the portions F′.

An example of moulding done on a Pridmore machine is shown in Figs. 168 to 172. Fig. 168 is the toothed wheel to be moulded. Fig. 169 illustrates the parts required for the bottom part of the mould. The pattern is of the same depth as the rim, plus the thickness for "making down," and half the depth of the interior of the wheel, that is down to the central plane of the arms. The pattern-carrying plate A, shown separately in Fig. 170, is screwed on the yoke frame B of the machine. A stripping plate, shown at C is necessary, attached to the outer framing D of the machine. In the Pridmore designs the stripping plate is cheaply formed by pouring white metal round the edges

lower face of which lies on the turn-over table of the machine. The next figures show the pedestal patterns C mounted on their pattern box D, with ingates to each, and covered by the bottom moulding box E. F is the "carrying plate," on which the mould and box is run away from the machine, after ramming and turning over. The lugs a, a are the means by which the boxes are clamped to the machine table during ramming, by means of clips. In Fig. 167 the moulding of the caps proceeds on similar lines, the respective boxes, &c., being

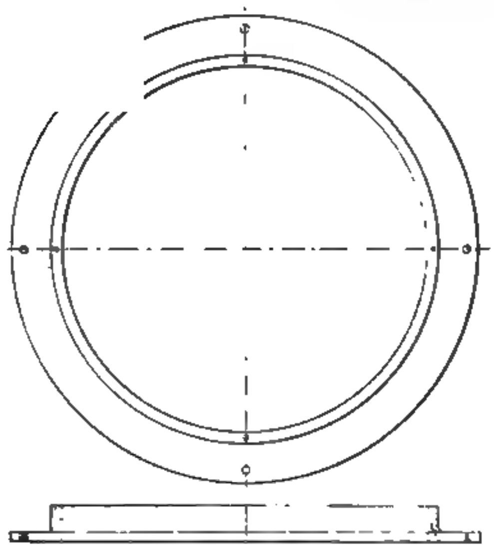


Fig. 170.—Pattern-carrying Plate.

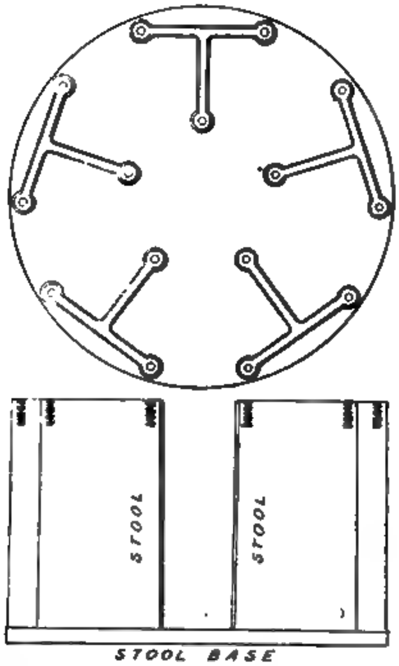


Fig. 171.—Stools.

of the pattern, and within a cast-iron frame. This is seen in Fig. 169. The provision for lifting the sand between the arms without fracture is that of "stools," attached to a base, and shown separately in Fig. 171. The stool base is bolted to the lower part of the main machine framing. The function of the stool plates is that of stripping plates to the arms. The triangular section is imparted to the stools to combine lightness with rigidity. The pattern parts for the top are shown in Fig. 172, and comprise internal portions only, forming the second half thickness, and carrying stools, and stool plates. *See also* **Moulding Machines.**

Machine Shop.—This is a rather comprehensive term. In strictness it includes only the machines other than the lathes, which are relegated to the turnery. But in many machine shops the lathes are included, often interspersed among the machines; and fitters' benches may be ranged down one side, or along the centre, or occupy one end. The term is sometimes even applied to the fitting shop itself.

Restricting the term to its legitimate meaning; the large machine shops have their areas subdivided into light and heavy departments, and into sub-departments, when turret work, gear cutting, and grinding are carried on extensively. Not unfrequently, too, the heavy or light machines of a kind are grouped; as planers, milling machines, vertical boring mills, and so on. When large volumes of work are done this facilitates output, not only because similar

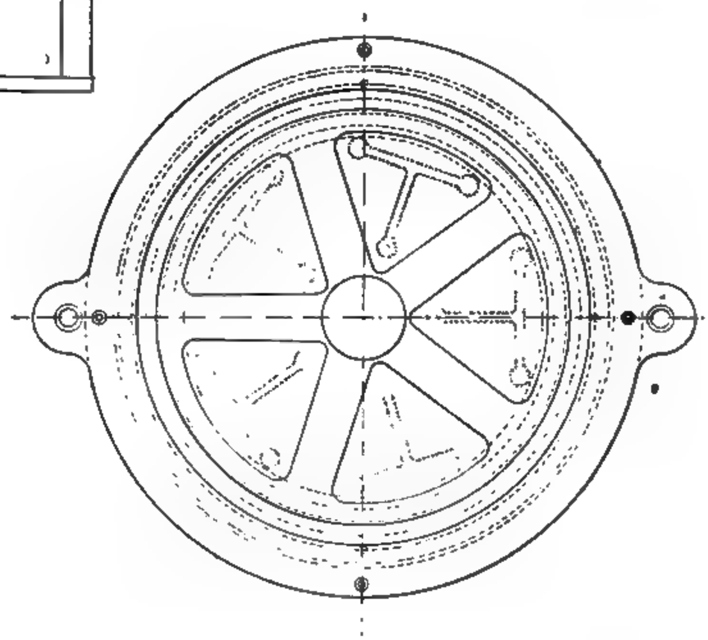


Fig. 172.—Pattern Arrangement for Top Part of Mould.

PLATE XI.

Fig. 159.—Log Frame Saw (Roller Feed).
(T. Robinson & Son, Ltd.)

Fig. 160.—Log Frame Saw (Rack Feed).
(T. Robinson & Son, Ltd.)

Fig. 173.—Machine Shop. (Lancashire and Yorkshire Railway.)

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operations are being carried on adjacent, but because hoisting and conveying tackle can be located suitably to the group of work. The unnecessary handling of work is avoided, and supervision is easier.

Arrangements of Shops.—Speaking in general terms only of the shop arrangements, two broad cases arise; that of heavy, and that of light articles of manufacture. Both are usually found in the same factory, but in greatly varying relations, one or the other predominating. Now, clearly the works must be laid out for the most economical treatment of the leading product, to which the lesser must be subordinated, and that will in some cases have a vital influence on the general design selected. For example, a burning question in almost any factory is whether a works shall be laid out as a ground floor only, or in buildings having upper stories also, and opinion is much divided with regard to this matter. When a firm's product consists of heavy work only, there need be no hesitation about the decision, but when it comprises a large volume of light work in addition to heavy, there is no objection at all to upper stories, or to galleries above the ground area, while if no heavy work is done, ground is wasted if storied buildings are not utilised. Alternatively, shops can be built with ground areas only for heavy work, and other shops with stories. In and near large towns, where land is dear, it often becomes necessary to put up with the inconvenience of working on floors. Then only light fitting, light lathes, and machines, pattern work and joinery should be done on the floors, and all the heavy work of all kinds below.

For lifting heavy work bodily in a large shop, the overhead traveller has no rival worth consideration. It is necessary that the shop in which it is contained shall run parallel, but no other shape should be built. The traveller is entirely clear of everything, and with its crab covers the entire shop area. Electricity is the best motive power to employ. For rapid handling of light work light travellers are used. But these have rivals in the jib cranes, actuated by hand, steam, electricity, or compressed air, and by the overhead hoists travelling on tracks or on swinging jibs, and also operated by compressed air. The question of the most suitable types for service cannot be discussed in brief. Frequency of handling work, whether being constantly done, or only occasionally would influence the choice, as also would the nature of the power plant already laid down, or in contemplation.

Fig. 173, Plate XI., and Fig. 174, Plate XII., illustrate machine shops.

Machine Shop Stores. — These have assumed great importance of late years in connection with modern manufacturing methods. Given a specialised class of product, and an interchangeable system, the finished stores become an essential feature. Similar parts are made by dozens, scores, or hundreds, depending on their dimensions, and frequency of recurrence in a mechanism. They are then sent into the stores as stock, and charged out again to the assemblers, or erectors. Hence every stores will be a reflection of the work done in a given shop. Articles are stocked by names and numbers, and are arranged in bins or shelves mostly when of small dimensions; but heavy work is laid upon benches, and the heaviest on floor areas. Fig. 175, Plate XII., illustrates a typical machine shop stores.

Machine Tools.—Tools of all kinds which are operated by machines. The original crude method of fixing a hand tool in a rest or holder, and operating it by self-acting mechanism, has been so extended and modified that the simple principle is disguised. It is so in machines which carry tools that could not possibly be operated by hand, and in others the tools for which have been invented and developed since the era of machine tools, notably the multiple cutting, and drilling machines, the milling machines, grinders, keyseaters, &c.

Descriptions of all the important machines are given in these volumes under their proper headings. Here we need only remark on their natural classification. They might be regarded from two points of view: the kinds of cutting tools used in the machine, or the character of the operations performed in it. Both have to be taken into consideration in the conduct of the machine shop, since the results are frequently the same, though entirely different kinds of machines are used. Thus, plane surfaces are produced with single-edged cutting tools, with milling cutters, and with grinding wheels; and so of others.

A comprehensive division of machine tools is that into: (1) Reciprocating; (2) Rotary; (3) Combinations of the two, with regular or irregular contours. Or: (1) Machines using tools having single cutting edges; (2) Those employing tools having a multitude of cutting edges; (3) Grinding machines. But there is no special value in such a classification from the point of view of the machine shop manager. He has to determine the best way to produce a given surface. Thus, taking:—

(1.) *Plane Surfaces.*—These are produced by planing, shaping, slotting, milling, or grinding, in machines that vary in design and dimensions. The results, considered with regard to economy and degree of accuracy, may or may not be equal, and these have to determine the choice.

(2.) *Cylindrical Surfaces.* — These are (*a*) external, or (*b*) internal. The lathe is the machine tool which is used more than any other for this work, but chiefly for the first; the second, unless combined with turning, being done chiefly in boring and drilling machines. Other tools used for (*a*) are, to a limited extent, the slotting, and shaping machines, and largely the milling machines of vertical type, also for (*b*); and the grinding wheels largely for both, and for roughing as well as finishing, though mostly for the latter. The machining of external surfaces by milling or grinding is one of the later developments of machine tools.

(3.) *The machining of irregular outlines* is work for the slotter, and shaper, and the milling machine. It may be done, as in the first two, with single-edged tools, by operating the work table having plain or compound slides, or in the vertical milling machine similarly; or by gang, and profile mills. Another kind of irregular outline is that reproduced from a form, and a tracer pin to control the milling tool.

Screw Cutting.—A class that stands alone is that for screw cutting, which is done by a combination of rotary and traverse movements in definite ratios. This is done in turning lathes, in special chasing and screwing machines, and in turret lathes, and automatic screw machines. It is performed by a guide screw of constant pitch, and change wheels to give the ratios; by a master screw, or hob of the same pitch as the screw to be cut, and comb tools; or by dies and taps drawn over, or thrust into the work, either the tools, or the work revolving. In most machines screw cutting or screwing is combined with provision for turning, cutting off, knurling, and other operations.

Machine Vice. — This differs from the **Bench Vice** in being constructed with greater accuracy in order that it may be used to hold work on the tables of planing, shaping, slotting, milling, drilling, and grinding machines. The methods of clamping by bolts and clips, applied in the case of large or awkwardly-shaped pieces, are not suitable for small and plain objects, either because of the difficulty of placing the clips, or because too much time would be occupied thereby. By the use of a suitable vice, moreover, work may be turned into several angular positions, and tooling done with precision.

The ordinary vice comprises a base piece with a fixed jaw, and a sliding jaw pushed up by a screw operated with a handle. The faces of the jaws are covered with hardened steel strips, plain or hatched. The base is made with slots or ledges, by which it is held down upon the machine table. All the parts must be made parallel and square to produce true work.

A vice of different construction to that usually followed is shown in Fig. 176, by Charles Taylor. The long screw is dispensed with, and special jaws are fitted to pull the work downwards. The base A, provided with lugs and bolt holes for holding down, has a loose jaw B, fitting in the central slot of A by a circular portion and a shoulder, which allows of its swivelling to suit tapered work. A grip-plate, C, can be slid to any longitudinal position to engage by two teeth on its back, seen clearly in the plan view, in serrations on the top of the base A. The screw E, turned by tommy holes with the lever F (chained loosely to the base), presses on a hardened steel stud let into the back of B, and forces the latter against the work. The loose jaws D, one of which is shown enlarged, each stand upon a curved spring, and fit by an inclined face, so that as the pressure comes on, the jaws slide downwards slightly and pull the work with them, ensuring a firm seat-

PLATE XII.

Fig. 174.—Machine Shop. (Marshall, Sons, & Co., Ltd.)

Fig. 175.—Machine Shop Stores. (Marshall, Sons, & Co., Ltd.)

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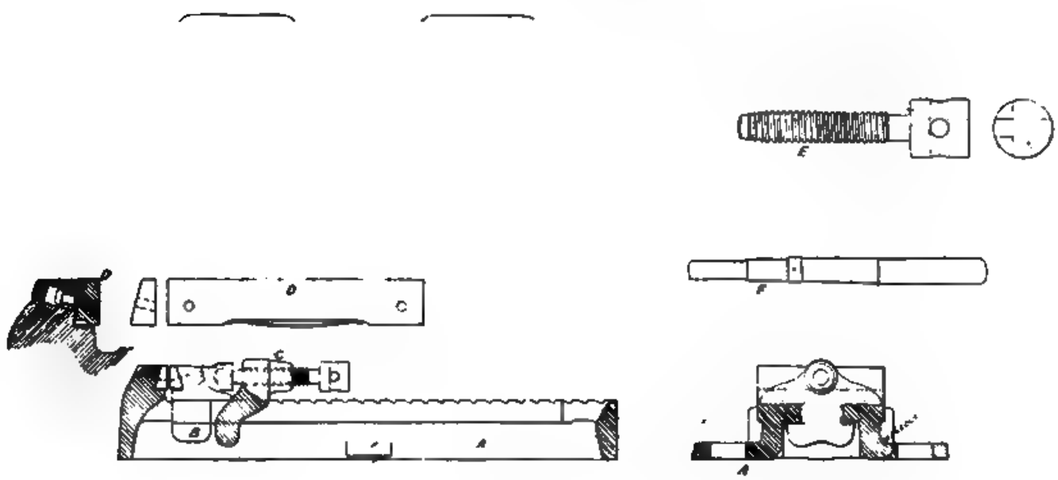

Fig. 176.—Machine Vice.

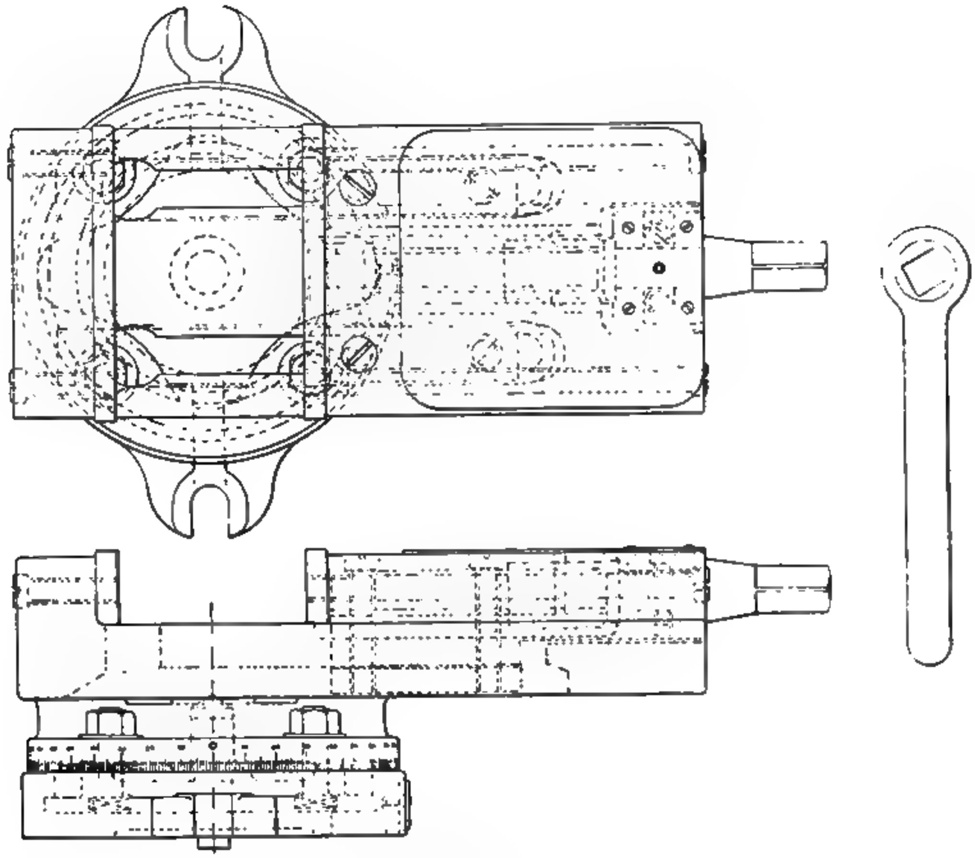

Fig. 177.—Swivel Machine Vice.

ing. They are prevented from falling off by a couple of screws sunk into holes in A and B, provided with spiral springs under the heads to allow for the motions of the jaws D, and covered in with grub screws. The curved springs underneath the jaws raise them after releasing the work, in readiness for another job. By this device the hammering down of work usually done in ordinary vices is avoided, and a better seating is secured. There is a clear space down between the jaws, owing to the absence of a long central screw, so that drills or other tools may clear through the work freely. Vices of this type are also made with swivelling bases and tilting arms, to angle the work into any position. The loose jaws may be shaped specially to suit repetition work if necessary.

There is another vice, the Jordan, in which rapid adjustment is effected by means of grooves on the base, into which a flat strip is inserted, and retains a push jaw from which set-screws press against a sliding jaw, which is prevented from rising by a couple of bolts.

Fig. 177 illustrates a swivel vice, with graduated base, used especially for milling and grinding machines. The loose jaws are held on with long screws passing through from the rear. The sliding jaw is prevented from tipping by screws and blocks underneath.

When very long work, beyond the capacity of the ordinary vice opening, has to be held upon a table, two or more loose jaws pushed up with screws are placed at suitable distances apart and clamped to the table. Some vices have reversible jaws to point backwards, and so in combination with a second vice form an opening of any desired width.

A loose pair of pivoted jaws is often inserted between those of an ordinary vice, to accommodate tapered work, instead of making the actual jaw to swivel. A pair of small point centres are also sometimes screwed on the top of each jaw of a planer or shaper vice, by which circular pieces are held with their countersunk holes in the ends.

MacNaughting.—A term which was common between about 1850 and 1870, to signify the conversion of old type low-pressure condensing beam engines into compound. The term was derived from the name of the inventor, W. M'Naught. A new high-pressure cylinder was fitted at the opposite end of the beam from the low-pressure cylinder, the steam after doing work in the first passing into the second and thence to the condenser. This divides honour with the rather earlier compound engine of Simms, as putting the principle of compounding on a practical basis.

Magazine Feeds.—When pieces of work cannot be produced in continuous fashion from a rod, or bar, or sheet, or strip of metal in automatic machines, some form of magazine is necessary to carry and feed the single detached pieces into position for cutting or stamping. There are several types of feeds, including shutes, and rotating discs for carrying a line of pieces either in actual contact with each other, or placed in separate pockets.

In automatic screw machines there are two classes of articles which are fed with magazines —studs and pins of various kinds that cannot be completely finished at one operation, and must be reversed end for end, and castings and stampings which are too large to be produced from bar. In the first case the feeding-in may be done through the hollow spindle; in the second, the pieces may be passed vertically down to the nose chuck at the front.

Power presses usually have a circular dial, provided with a number of holes in a circle, each of which receives a partially cupped or otherwise partially finished article. Part rotation of the dial is effected by a ratchet device operated from the crankshaft of the press, and the only duty of the attendant is to keep the pockets supplied with pieces. It would be impossible, or at least dangerous, to attempt to place the objects directly in position under the ram, so that it is preferable to let the dial feed them there instead. Locking of the dial is effected by positive mechanism, to ensure that all the holes come into accurate alignment with the ram punch.

Magnalium.—The name given to various alloys of magnesium with aluminium. With less than 10 per cent. of magnesium the alloy rolls well. With 10 parts of magnesium to 100 of aluminium the material has the mechanical properties of rolled zinc, with 15 parts it

resembles cast brass, with from 20 to 25 parts the alloy resembles hard drawn brass. Sodium, carbon and nitrogen, in the aluminium cause the alloys to be of no value. The presence of tungsten, nickel, and copper does not harm beyond increasing the specific gravity of the alloys. The addition of 10 to 15 per cent. of antimony raises the melting point from 700° C. to a white heat. Magnalium can be turned, drilled, and milled. When being filed it resembles soft brass. It takes a permanent silvery polish. It is harder than pure aluminium, and shows a finely grained surface on fracture, somewhat resembling that of steel. It can be soldered. The sp. gr. of magnalium is about 2·5. Its tensile strength is from 20 to 24 kilos. per square metre, or 12·7 to 15·2 tons per square inch.

Magnesite.—An impure magnesia with small quantities of silica, oxide of iron, alumina, and lime, with carbonic acid. It is used to a slight extent for the linings of basic Siemens furnaces, but is more costly than silica bricks.

Magnet.—The property possessed by magnetite, Fe_3O_4, of attracting small pieces of iron and steel, was known to the ancients. In the tenth or twelfth century it was also found that when suspended by a thread these natural magnets pointed north and south; hence the name "lodestone" or "leading stone," applied because of its use in navigation. This ore of iron is found in Arkansas, Spain, and Sweden, though not always possessing magnetic properties. Artificial magnets are made of iron, steel, cobalt, and nickel; cerium, chromium, and alloys of copper, aluminium, and manganese are also magnetic. Pieces of these metals rubbed with a lodestone or another magnet become magnets themselves. The attractive power is situated at the two "poles," these being distinguished as north and south, according as they turn to these points when the magnetised needle or bar is free to move. The imaginary line joining the poles is the magnetic axis. A magnet cannot have one pole only. Moreover, if a magnet be broken into many short lengths, each individual piece becomes a separate magnet, with its two opposite poles. If two magnets be brought together, it is found that a north pole attracts a south pole, and *vice versa*, but similar poles repel each other, *i.e.*, unlike poles attract each other, like poles repel each other. And the force exerted between two magnetic poles is proportional to the product of their strength, and inversely proportional to the square of the distance between them. (A unit magnetic pole is one which exerts unit force—one **Dyne**—on a pole of equal strength placed at unit distance—one centimetre—from it.)

The lines of forces between the poles and in the neighbourhood of a magnet are rendered visible by placing a sheet of thin glass over a magnet, and sprinkling iron filings over the glass. On tapping it, these filings at once fall into an interesting series of curved lines from the north pole to the south pole—magnetic phenomena are, like electric phenomena, always circuital. These curves are an actual plan of the stresses existing in the neighbourhood of the poles of the magnet, and the area over which they are spread is called the magnetic field. The magnetic force is most intense in the immediate neighbourhood of the pole, and falls off inversely as the square of the distance from the pole.

The total number of lines of force proceeding from a pole is called the magnetic flux of that pole, and the flux density, denoted by the letter B, is the number of lines of force per unit of area crossing a surface taken at right angles to the direction of the lines of force. If B is known, the pull between two flat magnet poles may be found from the formula:—

$$P = \frac{B^2 \times A}{72,134,000},$$

A being the surface area, in square inches, of each pole, B the flux density per square inch, and P the pull in pounds. The ratio between B and H, the intensity of field, gives what is known as the "permeability" of the substance magnetised. $\frac{B}{H} = \mu$. By permeability is meant the magnetic conductivity of any material, and this varies. Iron is very permeable, and for this and the other magnetic metals mentioned above the coefficient is greater than unity; for air the coefficient may be considered as unity; and less than unity for what are known as

diamagnetic materials, which are repelled from a magnet, and in which a magnetising force is able to induce fewer lines of induction than in iron and air. Bismuth, phosphorus, antimony, zinc, lead, silver, copper, gold, sulphur, water, and air are more or less diamagnetic.

A magnet may be "super-saturated," that is, it will lift a greater weight immediately after magnetisation than it will habitually do afterwards, when it falls to the point of "saturation." When a magnet loses its magnetism either slowly or rapidly, as in the case of soft iron, there always remains a small quantity of "residual" magnetism.

The extent to which various bodies retain their magnetism varies. The retentivity of hard-tempered steel is very great, and that of soft iron very small, although the former is magnetised with more difficulty than the latter. Moreover a tap or rough usage is sufficient to destroy the slight retentivity of soft annealed iron. Temperature also considerably affects magnetism. Great heat destroys the magnetic properties of most metals; in the case of cast iron heating to a red heat only, is sufficient. Chilling increases strength, although severe cooling destroys the magnetism of steel magnets.

Permanent, powerful magnets are built up with a number of thin sheets or laminæ, each separately magnetised. Such a magnet is in reality a collection of magnets, in fact, a magnetic magazine or battery. As regards shape, magnets are bar-shaped, horse-shoe shaped (a more permanent form, as the lines of force have less tendency to return through the metal), and ring-shaped.

But the vast and undreamt of commercial possibilities of magnetism were not thought of until the development of the electro-magnet. It was found in 1820 that very powerful magnets could be artificially made by causing a current of electricity to circulate through a spiral coil of wire enclosing a bar of iron or steel, the wire being insulated by being overspun with silk or cotton. Such an electro-magnet is more powerful than the ordinary magnet, and has the additional advantage of acting magnetically only as long as the current flows, ceasing to act when the circuit is broken; moreover it can be operated at any distance.

Various forms of electro-magnets are in use. The iron core may be in the form of a horseshoe, the coils being divided into two parts wound on bobbins. A similar type is used for electric bells: two cores are connected with an iron cross-piece or "yoke," the bobbins bearing the wire being slipped over the cores, and the wires connected. A very powerful pull is obtained with a short cylindrical electro-magnet, surrounded by an external iron jacket.

The amount of magnetism in the core depends on the intensity of the magnetising force, and the quality, length, form, and sectional area of the iron. Many formulæ are in use for calculating the magnetism of an electro-magnet, denoted by the letter m. The Lenz and Jacobi formula is $m = anC$, in which a is a constant, varying with the form, quality, &c., of the iron, n the number of turns of wire in the coil, and C the current. According to Lamont and Frölich, $m = B\frac{nC}{1 + \sigma nC}$ where B and σ are constants varying with the quality, &c., of the iron, σ being the reciprocal of the number of ampère turns which brings the magnetism up to half saturation.

A rather interesting development in the use of magnets has taken place in recent years. Cranes are now equipped with powerful magnets for lifting and carrying ingots, iron and steel plates, &c. *See* **Lifting Magnet, Dynamo**.

Magnetic Brake.—A device for producing a braking effect by the pull of an electro-magnet; either to operate a system of levers, straps, or friction discs, or to produce magnetic friction between two attracted surfaces, or a combination of both effects. Magnetically-operated brakes are much used on electrically-driven machinery, such as plate rolls, planers, &c., and also on electric cranes where it is desirable to bring the motor to rest for reversing the machines driven, or to sustain a suspended load. In such cases the braking is by mechanical means. Straps, blocks, or friction discs are operated by springs or weights, the magnet being used to release the machine by pulling against the holding power of the brake. The magnet coils are connected in series with, or as a shunt circuit to the motor, according to requirements (*see* **Electric Brake**), but in

either case are operated by the same controller handle as the motor.

Thus whenever current is supplied to the motor, the brake magnet also operates, and releasing the brake, continues to hold it free so long as the motor runs. Immediately the power is switched off, the magnet releases its hold and the brake is again applied. By this arrangement the machinery may be stopped as quickly as desired, held fast at a standstill until the motor is restarted or reversed, whilst, should any accidental failure of power occur, the brake automatically takes charge of the load. The convenience of this control in various kinds of work is considerable, whilst for electric cranes, capstans, &c., it is of the greatest importance.

The magnetic brake, now much used for tramcar service, consists of a series-wound magnet, carrying a heavy brake shoe hinged with link levers from its armature, the shoe being suspended just clear of the track rails. Special arrangements are provided in the controller to operate the brake, which can if desired be used as the ordinary service brake.

When the car has to be stopped, the power is switched off the motors, but as the momentum of the car carries it forward they are kept running. They are then working as dynamos, and would continue to run as unloaded generators until the momentum of the car was exhausted. Should, however, the magnet coils be connected across their armatures, the momentum is converted into electric energy. This energy induces a strong magnetic attraction, which, acting upon the magnet armature, pulls it upward. The links being so arranged, this attraction is converted into a downward thrust upon the brake shoes, producing a powerful frictional brake upon the track rail. The metal shoes being also magnetised tend also to cling to the rail, offering a considerable resistance to the movement of the car. Thus a very powerful braking effect is obtained, which, strong at first, gradually decreases as the speed decreases, but is nevertheless sufficiently strong to hold on until the car is brought to a standstill. Regulating steps may also be provided, so that the speed in coasting may be perfectly under control, a gradual and easy pulling up, or a sudden and powerful emergency stop effected. In some instances the track brake has also been connected to levers operating at the same time brake blocks on the running wheels.

The advisability of braking the wheels at all has been much discussed, owing to the skidding of the wheel which may occur under certain conditions of the rails. A recent improvement provides that the magnetic brake may be applied and regulated at will either by the motor generating, or direct from the line, so that the car may be held stationary on an incline, thus removing the necessity for the dangerous hand-brake which has been the cause of many accidents.

Magnetic Chuck.—This is employed on machine tools, including lathes, planers, shapers, milling and grinding machines, to hold work of comparatively light character, in iron and steel. It saves much time in chucking, and is eminently suitable for small pieces that are only held for a brief period, where the time occupied in manipulating bolts and clamps, or a screw vice, would be objectionable. The Walker chuck, Fig. 178, for the lathe consists of a body, A, having four magnet cores, B, cast with it. The energising coils are wound upon bobbins, C, encircling these cores. A cover plate, D, is screwed on to A, and is slotted out to hold four segments, E, screwed to the cores, B, but separated from D by strips of non-magnetic metal, thus turning the face into a surface broken up by eight gaps, and forming poles at each section of the plate and segments.

The current is brought to the rotating chuck by brushes pressing on collector rings at F and G, separated from each other by insulation. Screws holding the rings on also serve as a medium for conveying the current to the bobbins. The face plate which fits on the lathe mandrel nose is screwed to the back of the chuck in the recess inside the collector rings. The four T-slots seen on the face of the chuck are to carry bolts and small plates which prevent the risk of work skidding sideways under the pressure of the tool; they also serve to centre work, by leaving three of them fixed, and shifting the fourth to remove or insert the piece.

Fig. 179, Plate XIII., shows a chuck fitted

to the lathe, with a ring held on the face. The wire carrying current is seen on the right, together with the switch, and the brushes.

Flat or oblong chucks for use on the planer, shaper, or miller are constructed on the same principle, with a large number of non-magnetic gaps on the face. Shoulder pieces are fitted to butt the work against, and two or three bolt clips are used to prevent skidding. When a number of pieces are held side by side, additional holding power is obtained by inserting strips of non-magnetic metal between them. The most delicate and thin pieces may be held on these chucks without fear of distortion.

A chuck for holding work on a small grinding machine is illustrated in Fig. 180, Plate XIII. The body is held in swivel bearings for dealing with angular work. When parallel pieces are being ground wedges are slipped beneath the body, as seen, to retain it in correct position.

Magnetic Ores.—*See* **Iron.**

Magnetic Separator.—A device or machine for separating iron and steel from other materials. Brass foundries often use a row of bar magnets held in a stock, with a handle. This being moved about among the turnings and borings which have to be remelted, removes the particles of steel and iron from brass and gun-metal. But the process is slow when considerable quantities have to be worked through, hence machines are used in the larger foundries. Favourite forms comprise a rotating drum, carrying magnets on which the turnings are dropped from a hopper. The brass falls away, and the iron is brushed off. In another form, magnets arranged on a revolving disc are

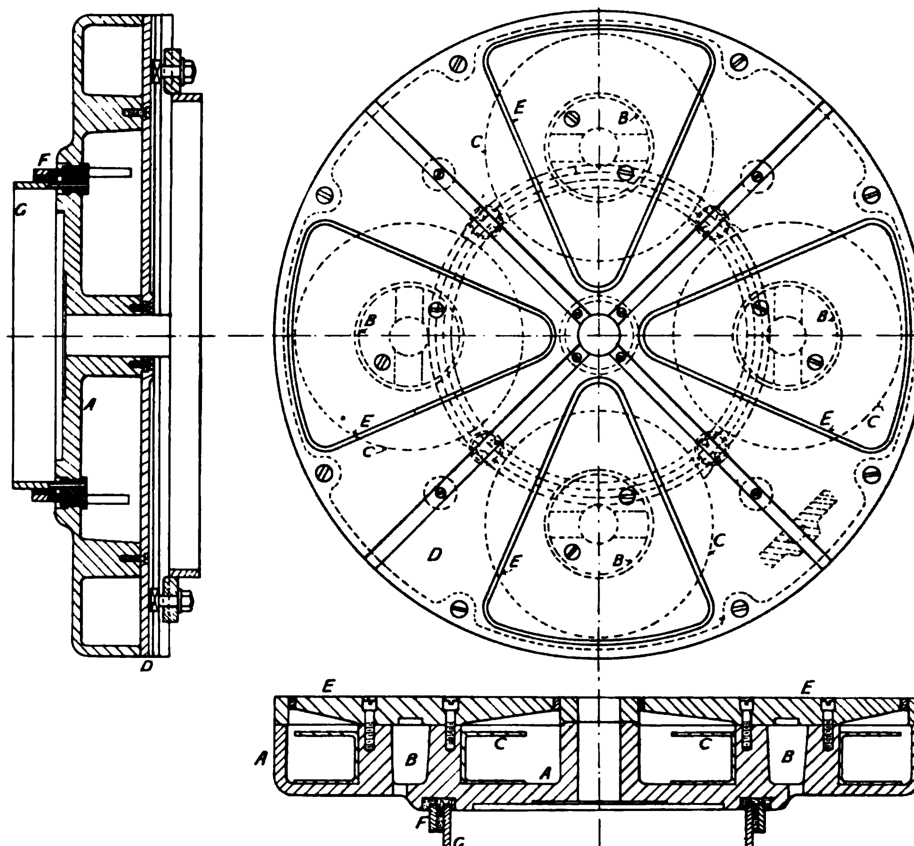

Fig. 178.—Magnetic Chuck.

Fig. 179.—Magnetic Chuck in Lathe.

Fig. 180.—Magnetic Chuck on Grinder.

Fig. 188.—Measuring Machine.

Fig. 190.—Measuring Machine.

(Newall Engineering Co., Ltd.)

Fig. 199.—Mercury Vapour Lamp.

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used. The magnets are automatically charged, and demagnetised, the latter taking place at the location where the iron particles are required to be dropped off. The same device is applied to some drum machines.

Another type of separator is designed for recovering the particles of iron shots and scrap that accumulate in the floor sand, in the fettling room, and in cupola slag. The separation is effected in an inclined revolving drum fitted with hopper and discharge shoot.

Another design of magnetic séparator is used for removing iron from materials which have to be crushed and ground, such as bones. One of these, by the Hardy Patent Pick Co., Ltd., has a cylinder rotating on rollers, with its axis at a slight inclination, so that material passes from the higher to the lower end. There are about eight magnets inside the cylinder extending along the greater part of its length, and projecting within it. They are excited by a dynamo, with which they are automatically connected and disconnected during a revolution of the cylinder. A tray or shoot is fixed within the cylinder, but unconnected with it. When the magnets are passing above the tray they are disconnected from the dynamo, and so drop the particles of iron on the tray. During the remainder of the revolution they are magnetised by the dynamo. The movements are so timed that a piece of iron would have to pass over the magnets about 120 times in its passage from one end of the separator to the other, so that its chance of escape without being picked up is nil.

Mahogany (*Swietenia mahagoni*), Nat. order Cedrelaceæ, sp. gr. ·56 to ·85.—Mahogany wood is obtained from the West Indian islands and the adjacent mainland of Central America. The best is known as Spanish mahogany, and grows on the islands of Cuba, St Domingo, and Jamaica. The other main variety is called Baywood, or Honduras mahogany, and comes from the vicinity of Honduras Bay. Spanish mahogany is chiefly used in cabinet work, its rich dark red colour and wavy grain making a better appearance than the straight grain, lighter colour, and slightly softer character of Honduras mahogany or baywood. For many purposes, however, the latter is preferred because of its straight grain and the greater ease with which it can be worked, while it also has an advantage in being obtainable in larger sizes than the Spanish. It is also lighter in weight. The quality of baywood varies and is sometimes very poor through sponginess. Spanish mahogany can always be distinguished from Honduras by a white substance appearing as specks in its surface, similar specks in Honduras being dark. Both trees attain very large dimensions, and the wood does not warp or shrink or crack to the extent that most other woods do. This makes it suitable for furniture and interior fittings, and for any work that must be exact and permanent. It does not stand exposure to the weather well. It is employed a great deal for the woodwork of railway carriages and ships. It is also often used in pattern-making, especially for small patterns from which a great number of castings have to be made. A mahogany pattern will stand more service than one of pine, but its first cost is greater because of the extra value of the wood and the slightly greater trouble of working it.

Malleability.—The property possessed by metals in virtue of which they can be hammered, rolled, or pressed into flat sheets. There is a relation between this property and softness and tenacity, though the softest metals are not always the most malleable, and the most tenacious metals are not the most easily hammered. The metals stand as follows in order of malleability: gold, silver, copper, tin, platinum, lead, zinc, iron, nickel. Malleability is affected by (1) heat, (2) the presence of impurities. As a rule, thick metals are more malleable when hot than cold, while little difference is noticeable in the case of thin metals. This makes an essential difference in the methods of working sheet metal of the boiler-maker, and of the sheet-metal worker. The term "cold short" is applied to metals which are malleable when hot but not when cold, and "hot short" to those which are malleable when cold but not when hot. The presence of phosphorus in iron causes it to be malleable when hot, but brittle when cold, while the addition of sulphur has an opposite effect.

Malleable Cast Iron.—Cast iron from

which the carbon has been abstracted, leaving it in a tough and malleable state. The castings are moulded from patterns, as being cheaper to make than forgings, and are then decarbonised in a furnace in contact with a decarbonising material for several days.

Reaumur appears to have been the first to point out, in 1722, that iron castings embedded in red oxide of iron in the presence of heat would become softened. Lucas (1804) was the first to put the process on a commercial base. He said: "The pig or cast iron being first made or cast into such form as may be most convenient for the purpose for which it is afterwards intended, is to be put into a steel-converting, or other proper furnace, together with a suitable quantity of limestone, iron ore, some of the metallic oxides, lime, or any combination of these (previously reduced into powder or small pieces), or with any other substance capable of combining with, or absorbing the carbon of the crude iron. A degree of heat is then to be applied so intense as to effect an union of the carbon of the cast iron with the substance made use of, and continued so long a time as shall be found necessary to make the cast iron either partially or perfectly malleable, according to the purposes for which it may be wanted. . . . Five or six days and nights will in general be found sufficient during which to continue the heat. . . . The cast iron to be rendered malleable, and the substances to be made use of for that purpose may be placed in the furnace in alternate layers, and in order to prevent the iron stone, or iron ore from adhering to the iron, a thin layer of sand may be placed between them."

In the decarbonising process, oxygen is the essential agent, hence the wide choice of substances which can be used for packing the castings in. Hæmatite iron ore is the material generally used in England, in particles of about the size of peas. Spent, or previously used ore from the furnaces is mixed with the new or raw ore to prevent the too rapid oxidising action of the latter. In America the hammer, or mill scales are largely used. These are magnetic oxide of iron, Fe_3O_4, and they are preferred because free from earthy matter. Black oxide of manganese, and also sand mixed with ferrocyanide of potassium, have been employed. The temperature for annealing ranges between 800° Cent. and 900° Cent. The period of exposure varies with the mass of the castings, other conditions being the same. Castings must be packed in the boxes with those of larger mass outside. They must also be laid in such positions that they shall not become bent when the cementing material falls away. Long ones are placed vertically, and small ones are packed between large ones, with cementing material intervening.

The unreliability of many malleable iron castings is due to imperfect decarbonisation, and want of homogeneity, to the cracking of corners where thick and thin portions meet, to oxidisation, distortion, and unequal shrinkage. These evils are not insuperable, but their avoidance is a question of much experience and expense. Moreover it is impossible to get good castings unless the iron is of suitable chemical composition. Iron containing its carbon in the form of graphite is useless. It must be present as combined carbon, either of the white, or mottled variety. The mottled is often preferred because it runs better than the white. As in all such work, the runners must be larger than in grey iron castings. Sulphur and manganese are both undesirable elements. Phosphorus must be low. Silicon is helpful, as tending to fluidity. If perfectly decarbonised castings are required, re-annealing is practised, and this may be repeated twice or thrice.

The following table gives some results of re-annealing on cast iron.

	Original Cast Iron.	Malleable Cast Iron after two Annealings.	Original Cast Iron.	Malleable Cast Iron after two Annealings.
Total carbon	3·43	Less than 0·10	3·48	Less than 0·10
Silicon	0·445	0·614	0·585	0·449
Sulphur	0·059	0·162	0·105	0·083
Phosphorus	0·315	0·295	0·280	0·315
Manganese	0·529	0·575	0·585	0·325

A bar containing, when unannealed, 0·19 per cent. of graphite, and 3·69 per cent. of combined carbon, gave, after one annealing 0·36 per cent. of graphite, and 0·73 of combined car-

bon. After three annealings, graphite was *nil*, and there was only a trace of combined carbon.

The forms of annealing furnaces vary. Generally the malleable castings are laid in cast-iron boxes and packed around with the cementing material, the covers luted, and laid in layers in the furnace, which is then closed. The heat from the fire-grate passes around the boxes on its way to the chimney, and is regulated by dampers. But sometimes the cost of boxes is saved by packing the castings in the furnace, and bricking up the front. Either method is open to objection on economical grounds. Boxes have to be renewed after from six to twelve heats. The furnaces have to cool down before the castings can be withdrawn, and subsequently reheated for the next charging. Some furnaces therefore use trolleys on which boxes of iron or brick-work are run into place, and out, without the loss of heat.

The strength of malleable cast iron is not very high. It ranges from 16 to 20 tons tensile strength per square inch. Its elongation is from $1\frac{1}{2}$ to 4 per cent., with a similar contraction of area. It will undergo almost any amount of bending and twisting. But results depend largely on the quality of metal, its chemical composition, and the care with which annealing is done, so that no uniformity can be guaranteed for all castings.

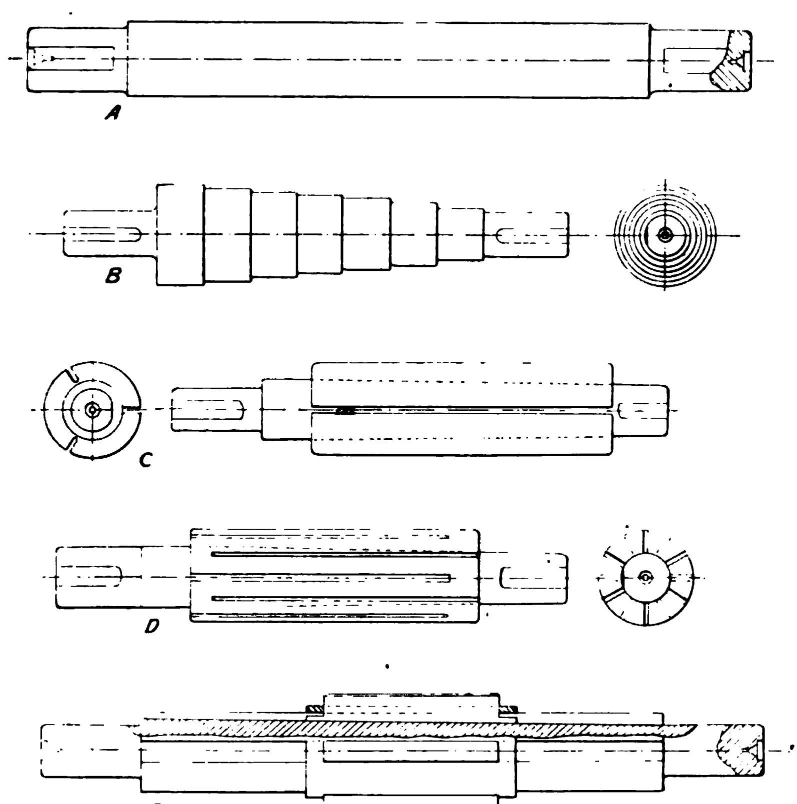


Fig. 181.—Mandrels.

Mallets. — Wooden hammers used by wood-workers, boilermakers, and sheet-metal workers. The wood-workers' mallet is used for driving chisels and gouges in heavy cutting. That of the boilermaker is employed for hammering red-hot plates, to avoid bruising them with steel hammers. That of the sheet-metal worker also bends without bruising.

Mandrel.—Applied to various classes of spindles, including those for lathes, and saws, but more properly restricted to the loose mandrels for chucking work to turn or grind it accurately with a central hole. The term Arbor is frequently used in America. A good mandrel should be turned or ground accurately along its length, with a very slight amount of taper, and the ends should be reduced, and made with flats to take a carrier, as in Fig. 181, A. The centre holes should be sunk in deeply and drilled in at the bottom to clear the point of the centre. By this sinking in, no damage can accrue to the centre hole, as the large recess preceding it prevents hammer blows or pressure from distorting the metal.

The objection to the solid mandrel is that it

only provides for one size of hole, and a shop needs a very large number to cope with the requirements of various work. Two alternatives are possible—stepped mandrels, and expanding mandrels. The first, B, are useful for narrow objects, one or other of the steps being used; the second take longer bores, and afford a moderate range of diameters, so that a set of six or eight will meet all the needs of a lathe or grinder. One of the simplest methods of expanding is that in C, in which the body is tapered to receive a bush parallel outside, and having three splits—one right through—which allow the bush to expand or contract slightly as the mandrel is driven in or out. Greater flexibility is secured by the bush in D, with an increased number of cuts, carried to each end alternately, making the sleeve very elastic.

A favourite method of producing expansion is by sliding loose jaws up inclined grooves; a good many mandrels are made on this plan. E is an example, the Nicholson, in which the body has four tapered grooves, carrying four blades, prevented from falling apart by an encircling casing through which they project. Tightening or loosening is effected by driving or forcing either end of the mandrel while the work is held stationary. Screw action is employed in some of these taper groove mandrels, the jaws, which are stepped, fitting by a head inside a circular screwed ring, which is moved along a threaded portion of the mandrel, to push the jaws inwards or outwards as they slide in the inclined grooves.

Mandrel Press.—A small appliance for forcing mandrels into and out of work by simple pressure, instead of using blows, as when a Mandrel Stand is employed. A framing carries a vertical ram, which is forced down by a rack and pinion operated with a handle, and the work is supported upon a disc, which may be revolved to bring any one of several differently-sized slots below the ram, to accommodate varying diameters of mandrels. The smallest presses stand upon the end of the lathe bed, if space permits. The larger machines have a separate stand, and gears are introduced to afford greater power, and a ratchet handle is sometimes used with a very long lever, or a hand-wheel is employed. Hydraulic presses are also made for mandrel forcing.

Mandrel Stand.—This is used in the machine shop, and consists of a hollow cast-iron pillar, in the top of which rings of various bores may be inserted, to receive mandrels which are driven into or out of work resting on the ring. A number of rings are required because of the various diameters of mandrels which are used. The mandrels fall through the hollow base when driven out of the piece, and are caught by the hand.

Manganese (Mn, 5·5; sp. gr., 8; melting point, about 1,900° Cent.).—This metal occurs in Nature as an oxide from which the pure metal is obtained by reduction. Manganese is a brittle, very hard (scratching glass and steel), reddish white metal, oxidising readily on exposure to air. It has therefore to be kept either in a sealed vessel or under naphtha. It decomposes water, hydrogen being evolved. Some of the oxides are used for tinting glass a purple colour, and the dioxide MnO_2 is also used as a depolariser in the Leclanché and dry cells.

Its various compounds with oxygen are—manganous oxide or manganese monoxide, MnO; manganic oxide or manganese sesquioxide, Mn_2O_3 (occurring as the mineral "braunite"); mangano-manganic or red oxide, Mn_3O_4 ("hausmannite"); the black oxide or manganese dioxide, MnO_2, called pyrolusite, and which yields a third of its oxygen on being heated to redness, $3MnO_2 = Mn_3O_4 + O_2$; oxygen is also evolved on heating the dioxide with sulphuric acid, $2MnO_2 + 2H_2SO_4 = 2MnSO_4 + O_2 + 2H_2O$; manganese trioxide, MnO_3; and manganese heptoxide, Mn_2O_7.

The pure metal is not used commercially, but is of great importance to the engineer in the formation of alloys of iron, steel, and copper. In steel, manganese increases tenacity, and reduces ductility. In commercial steels from ·3 to 1 per cent. of manganese is present. Crucible steels contain about ·14 per cent. The character of steel varies greatly with the percentage of manganese alloyed with it. Containing above 7 per cent. of manganese, steel becomes tough, and possesses great tensile strength. Below this amount, down to 2·5 per

cent., the alloy becomes very brittle. *See* **Manganese Steel**. In high-speed steels the proportion of manganese is reduced to a mere trace.

Manganese bronze contains only a trace of manganese. As manganese is added in the form of ferro-manganese a certain proportion of iron is present in this alloy. *See* **Manganese Bronze**.

Manganese Bronze.—A valuable alloy, which may or may not contain the merest trace of manganese. The only value of the manganese lies in helping the iron introduced to alloy with the copper. It is well known that iron will not alloy thoroughly with copper or brass unless aided by manganese or aluminium.

Though the fact had long been known that iron imparts strength to bronze, this method of introducing it was due to Parsons, without which the addition of iron alone would not have produced an alloy capable of being cast as a homogeneous alloy. Without it, portions of the iron would separate out. The following are analyses of Parsons' manganese bronze, in sheet, and in ingots for casting in sand.

ANALYSIS OF PARSONS' MANGANESE BRONZE.
(*Sheet.*)

Sample.	No. 1. Per Cent.	No. 2. Per Cent.
Copper	60·27	60·02
Zinc	37·52	37·70
Iron	1·41	1·53
Tin	0·75	0·72
Manganese	0·01	0.02
Lead	0·01	0·01

ANALYSIS OF PARSONS' MANGANESE BRONZE No. 2.
(*Ingots for Sand Casting.*)

Sample.	No. 1. Per Cent.	No. 2. Per Cent.
Copper	56·11	56·23
Zinc	41·34	41·16
Iron	1·30	1·41
Tin	0·75	0·68
Aluminium	0·47	0·51
Manganese	0·01	None.
Lead	0·02	0·01

The addition of iron to a copper-zinc alloy increases its strength and elastic limit. A little tin increases the elastic limit. The manganese is introduced in the form of an alloy with the iron, ferro-manganese, or "steel alloy," containing about 80 per cent. of manganese, 14 per cent. of iron, and 6 per cent. of carbon. Speigeleisen, which contains about 80 per cent. of iron and 20 per cent. of manganese, may also be used.

The ferro-manganese is broken into lumps and melted with wrought iron, and tin; 4 lb. of ferro to 18 lb. of wrought iron, and 10 lb. of tin, in a crucible and poured into ingots, to be broken before being melted with the copper and zinc, thus:—

About 15 lb. of ingot copper is melted in a crucible. Then 2 lb. of the steel alloy is added and melted, ½ lb. of aluminium is added for cast work, to clear or liquefy the mixture, the whole being stirred. Then about 40 lb. of copper are added, and melted, followed by 43 lb. of Bertha zinc. There will be a little waste of the zinc. The mixture is ingoted and remelted for use. If remelted more than once, 1 lb. of zinc should be added at each remelting. Any traces of manganese disappear in one or two remeltings.

The difference between manganese bronze as used for casting, and that for sheets and forgings is that the latter contains no aluminium, and that the proportion of copper is higher, to increase ductility.

Manganese bronze must be poured dull, and must not be melted hotter than is necessary to ensure running. For small castings a slight flaring or oxidation of the zinc marks the stage at which the alloy is sufficiently melted, for large ones it is not necessary. Overheated metal, and metal that is allowed to soak suffers injury. Test bars of good manganese bronze easily give the following results. Tensile strength, 70,000 lb. per square in.; elastic limit, 30,000 lb. per square in.; elongation in 6 in., 18 per cent.; reduction of area, 26 per cent.

Manganese Steel.—All ordinary steel contains some manganese, which may range from about 0·3 to 1 per cent. and which is necessary to prevent red-shortness. In the alloys, speigeleisen, or ferro-manganese, it is added to the charge in open-hearth, or

or diagonal engines. The marine steam turbine may be the engine of the future.

Confining our present notice to the inverted cylinder engines, these are either compounds; with two cylinders, or triple, or quadruple expansion, and the cylinders are side by side, as the tandem arrangement would occupy too much head room.

The engine builder is hampered by considerations of space much more on board ship than on land. This to a large extent helps to explain the reason for the chronological designs just now named; the oscillating, the trunk, the side lever, and the diagonal, all applied to paddles. The employment of the screw rendered these forms obsolete for ocean service.

In the inverted direct-acting engine the single cylinder is for several reasons not suitable for driving a screw steadily and economically. The features of the compounds, in which triple and quadruple expansions are included, are: moderate length of piston stroke and connecting rod, and all driving to a single crankshaft, to which the screw shaft is coupled. Compactness of arrangement is secured by the dispositions of condenser, and air and circulating pumps close to, or built into the supporting columns or standards, and in ready accessibility of parts for inspection and repairs. The large dimensions of the pistons and valves render balancing, and equilibrium arrangements essential. Barring engines, self-lubricating devices, and relief valves to the steam chests of low-pressure cylinders are necessary. Steam jacketing to the high-pressure cylinders is practically universal. The use of piston valves divides favour with that of double and treble ported slide-valves. Link motions are used. The crankshafts and cranks are made by building up with shrink fits.

Large marine engines of triple-expansion type generally have four cylinders; one high pressure, one intermediate, and two low pressure. The latter are placed outside at the end of the series. In some cases, as in some of the biggest liners, the four cylinder arrangement is different. The high-pressure cylinder is placed tandem on top of the intermediate cylinder, and the two low-pressure cylinders are arranged alongside the intermediate. This is only possible because of the great height between decks in these vessels.

The cylinders and valves of marine engines differ much in design. The practice of superheating has been fruitful in effecting recent alterations. The liners of cast iron have given place in modern engines to those of forged steel in high-pressure and intermediate cylinders, cast iron being retained for low-pressure cylinders. Often, however, the latter are not jacketed. Piston valves are commonly used for the high and intermediate-pressure cylinders, and flat side valves with relief rings for the low-pressure cylinders. Pistons for high and intermediate cylinders and their covers are generally of cast steel; sometimes the high-pressure piston is of forged steel. Cast iron is used for the others. Coned pistons and covers are universal.

Inclined cylinder engines are commonly used for river and coasting pleasure steamers, in which head room is insufficient for vertical engines. The cylinders are lowermost, generally two cylinders, compound; and their axes and the guide bars are inclined to the paddle shaft.

Marine Glue.—A cement formed of india-rubber, shellac, and mineral oil. It is used for making the joints of packing cases water-tight, strips of canvas saturated with it being laid along the joint edges.

Marine Oil Engine.—*See* **Oil Engine.**

Marking Gauge.—A wood-worker's gauge, having a nicker in the end of the stem for marking lines to be planed or cut by. The thickness of the timber is gauged between the nicker and the face of the head, which is adjustable along the stem, on which it is secured with a screw or wedge. A large gauge of this kind is termed a panel gauge.

Marking-off Table.—*See* **Lining Out.**

Marking Out.—*See* **Lining Out.**

Martensite.—A term given to the structure of steels which are quenched suddenly from high temperatures. Martensite, with the maximum amount of carbon, or say 0·9 per cent. of carbon, is called Hardenite.

Mass.—The quantity of matter in a body irrespective of its position on the globe, or in any other of the planetary bodies. It is dis-

tinct from the gravitation measure of force, which varies with latitude, and therefore the distinction has to be made in scientific work. For practical purposes mass and gravitation weight are identical. The force of gravity in London is to that at the Equator as 100,315 is to 100,000.

Mass Work.—*See* **Monolithic Work.**

Match Boarding.—Boards with tongues and grooves formed on their edges so that they will fit together edgewise. They are usually $\frac{1}{2}$ in., $\frac{5}{8}$ in., or $\frac{3}{4}$ in. thick. They are sold by the square, of 100 superficial feet. A bead is generally formed at the edges to improve the appearance and conceal slack joints. Match boarding is used for partitions, light wood houses, and many other purposes where large surfaces have to be boarded over.

Match Planes.—Planes used in pairs, one for cutting a groove in the edge of a board, and the other for forming a tongue to fit it. Formerly they were used for planing the edges of match boarding, but such work is now usually done by machinery, and match planes are rarely used. The commoner practice is to plough grooves and insert loose tongues.

Materials — Strengths of. — These are treated under specific heads.

Mathematics.—There are few trades or professions which demand a knowledge of so many sciences as engineering. Mathematics is, more than ever, one of the most essential of these sciences. To a workman it would be advantageous to have some knowledge of the rules of arithmetic (omitting, of course, such branches as interest, stocks, &c.), algebra (with special attention to equations), Euclid's propositions, the geometrical construction of angles and simple figures, mensuration, and trigonometry. But the student and draughtsman should aim at a much deeper and more comprehensive knowledge of mathematics. The syllabus of the Whitworth Scholarships and Exhibitions embraces, in the two divisions of mathematics, stages 2, 3, or 4, and 5, 6, or 7, the higher stages carrying higher marks. Such a knowledge of mathematics would include practically all the rules of arithmetic; Euclid up to and including the sixth book; in algebra, addition, subtraction, multiplication, division, G.C.M., L.C.M., factors, equations (including quadratics), involution and evolution, surds, ratio, proportion and variation, permutations and combinations, progressions, indices and binomial theorem; logarithms; plane and spherical trigonometry; solid, descriptive, and co-ordinate geometry; geometrical conics, differential and integral calculus; differential equations.

Matter.—At present it is impossible to give a satisfactory definition of matter. The old-fashioned definition of matter, as that which can be perceived, or that which occupies space, has been discarded. Physicists and chemists are now inclined to define matter as electricity. The atom, once regarded as the ultimate form of matter, is now known to be a sphere of positive electrification, containing a number of negatively electrified bodies called electrons or corpuscles; the number of these electrons in one atom may be many thousands, moving in some cases at the rate of 100,000 miles a second. At the moment of writing it is suspected that the mass of these electrons is due to their electrical charge. Thus mass, always associated hitherto with matter, may ultimately be an electrical phenomenon, and atoms of matter merely atoms of electricity.

But this view shatters what was considered as a fundamental truth, the conservation of matter. It is known that atoms may be unstable, that is, they may lose one or more of their electrons, one element being thereby changed into another. What is the fate of this negative electron hurled out of the unstable atom at such a tremendous rate? A French scientist likens its fate to that of an iceberg reaching warmer waters—the electron radiates its energy in the ether and ends its existence in producing vibrations of the ether.

Interesting as these newer theories are to the student, they are less important to the engineer than the properties of matter; in the metals especially he has to study these properties, with a view to their utilisation, to modify them where possible, and to ensure by experiment and calculation that these properties are not overtaxed. Most of these properties are dealt with under their respective titles. *Compressibility* is the property of matter by virtue of which its bulk is reduced by pressure; *cohesion*

is the mutual attraction of particles of matter; *hardness* among solids ranges between talc cut by the finger nail, and the diamond which cuts glass. Among common metals, steel and lead occupy the two extremes, iron, copper, silver, tin, and antimony ranging between these two in the degree of hardness possessed; *rigidity*, the quality of resisting change of form; *elasticity*, the ability of a body to resume its original bulk or form when the force which caused it to alter that bulk or form has been removed; steel possesses a greater degree of elasticity than wrought iron, wrought iron more than cast iron, and cast iron more than copper; *ductility*, by virtue of which certain metals may be drawn out into wire; iron, copper, zinc, tin, and lead represent the descending degree of ductility; *malleability*, a property which enables a body to be rolled, or pressed, or beaten out by hammering (Lat. *malleus*, a hammer); copper, tin, lead, zinc, and iron is the order in which these metals stand as regards malleability; *plasticity*, which makes a substance capable of being moulded; *tenacity*, enabling a material to resist forces tending to tear it asunder; tenacity is possessed by the following metals in the order shown: steel, wrought iron, copper, zinc, tin, lead; *gravitation*, the tendency of all bodies to fall to the centre of the earth; *inertia*, by which matter at rest tends to remain for ever at rest, and in motion to remain in motion; *capillarity*, the molecular attraction which occurs when one end of a tube of narrow bore is immersed in a liquid; *viscosity*, the property of matter by virtue of which it tends to resist the action of shearing forces; *diffusion*, the passing of one gas or liquid into the space occupied by another.

Mattrass.—A structure of brushwood used to train the course of a river. *See* **Foundations**. Also woven sheets of canvas, asbestos, and non-conducting materials used for covering boilers and similar vessels. It is made in sheets, usually of about 3 ft. wide and long, and in thicknesses from ½ in. to 2 in. It is secured with steel or brass bands similarly to other laggings.

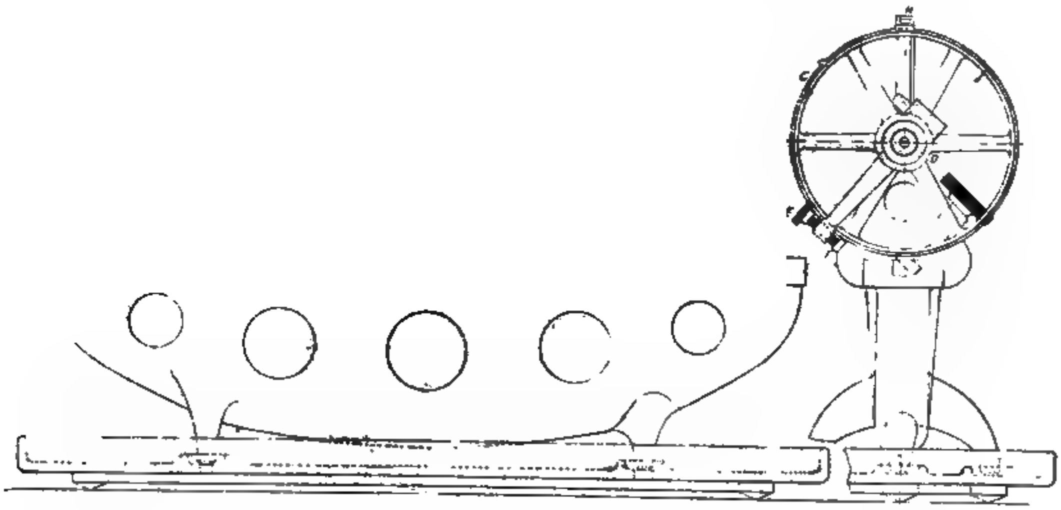


Fig 187.—Newall Measuring Machine.

Measuring Machines.—Most measuring machines are derived from the Whitworth original. The principle is the micrometric division of the pitch of a screw by means of a finely divided disc on one end of the screw. The necessity for machines capable of taking extremely delicate measurements is obvious. Rule measurement is of no value for these. The finest divisions on a rule, $\frac{1}{100}$ of an inch, cannot be measured accurately except with calipers. Yet $\frac{1}{100}$ in. is a coarse dimension. It can be read easily with a vernier caliper, but $\frac{1}{1000}$ in. is not read easily with a vernier. But the micrometer caliper reads this and finer

dimensions readily, so that it is possible to detect differences of about $\frac{2}{10000}$ in.

Modern practice demands that parts shall be produced so nearly accurate to size that they do not vary more than $\frac{1}{1000}$ in., and in many cases less. This explains the development of instruments which measure easily to these fine dimensions. But these demand rigid gauges used for reference, and instruments capable of fine and variable measurements also, for reference and test of the working gauges. If the ordinary productions of an engineer's shop are made accurately within $\frac{1}{1000}$ in., there must be a much smaller maximum permissible error on the gauges, and standards of length which are used for obtaining accuracy in the workshop. The generally accepted practice is that gauges shall not vary by more than $\frac{1}{10000}$ in. In order to produce gauges and standards of length to so fine a degree of accuracy it is necessary to have an instrument capable of measuring to something finer than $\frac{1}{10000}$ in. The example selected for illustration, Figs. 187, and 188, Plate XIII., by the Newall Engineering Co., Ltd., is capable of measuring to $\frac{1}{100000}$ in. It is difficult to realise what this means. It may be stated as about two hundred times finer than the diameter of a human hair.

The mechanism is mounted on a hollow casting, to permit circulation of air, and having a three-point support, and shaped also girder fashion to avoid all possible chance of flexure. A is the fast, and B the loose head. The personal element is eliminated in taking measurements. Thus, in place of the "feeler" or feeling piece usually applied to measuring machines, a spirit level indicator C, Fig. 187, is used to detect any contraction or expansion of the piece being measured, due to variations in temperature. The curvature of the level, and the movement of the bubble magnifies the movement of the piece four thousand times. The piece to be measured can be left between the points *a*, *a*, until all the parts, unequally warmed by handling, arrive at an even temperature. The final reading can then be taken without touching the machine. The measuring screw in the head A is of a coarse, deep pitch, with a movement of 1 in., and is supported by bearings at both ends. It can be rotated rapidly by a knurled nut D at the end of the spindle. It is rotated slowly by the knob E which is carried in a rocking lever attached to the screw spindle, and pushed away by the resistance of the bar F. G is the large divided wheel, which is rotated under the indicating or reading bar H above.

As a perfect screw cannot be manufactured, it is necessary, when external accuracy is required, to compensate for minute inaccuracies in the pitch, so that correct dimensions will be indicated on the machine. This is shown by Fig. 189. A lever A carries a roller B, which bears on the crest of a thread at the rear end of the spindle, and the pitch of which is equal to that of the measuring screw. Undulations made on the crest of this thread impart movement to the lever which carries the roller. As a spring always keeps the roller in contact, the lever conveys the movement to the upright arm C carrying the vernier (on which is the zero line). In this way the zero line on the vernier is moved to compensate for error in pitch at any point of the screw. The pitch of the screw is first tested against standards of known inaccuracy, and the compensating done accordingly.

The tailstock B, Fig. 187, is the movable head. End measuring rods are generally used for

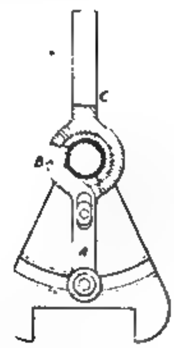


Fig. 189.—Compensating Device for Measuring Machine.

setting this, but the amount of their inaccuracy should be known. Another method is shown in the photo, Fig. 190, Plate XIII. The measuring screw has a traverse of 1 in. For sizes larger a rule is provided at one side of a body, and a microscope is attached to the tailstock. The

tailstock is moved bodily by the fine adjustment provided until the parallel lines in the microscope straddle the microscopic graduations on the rule. The rules are graduated on a highly polished surface of non-corrosive metal. The graduations can scarcely be seen by the naked eye, hence the necessity for the microscope.

Mechanical Advantage.—The force which a machine receives from an outside source is frequently less than the resistance overcome by the machine. The ratio of the resistance to the effort is called the mechanical advantage of the machine. Usually the effort and resistance are represented by the letters W and P.

$$\frac{W}{P} = \frac{\text{weight}}{\text{power}} \text{ or } \frac{\text{resistance}}{\text{effort}}.$$

For a machine to be mechanically advantageous this fraction should evidently be greater than unity. If it is less than unity the machine is said to work at a mechanical disadvantage. The mechanical advantage of the "mechanical powers" is discussed under their various titles.

Mechanical Engineering.—The practice includes that of several distinct trades, as drawing and design, pattern-making, founding, smith's work, plating, boilermaking, fitting, erecting, some departments of coppersmiths' work, testing, painting. Each trade being a distinct craft has to be acquired in apprenticeship, or the equivalent thereto, in a term of non-indentured service. It is followed by workmen who have no occupation or responsibility outside the shop or department in which they are engaged. These are not therefore engineers in the broad sense, since their labours are restricted to a single department only.

Mechanical engineering as a profession, embraces an intimate knowledge of these trades, with the scientific knowledge which underlies their practice. This does not necessarily mean skill in handicraft, but such knowledge as is gathered in a few months of pupilage, occupied in each of the principal shops, supplemented by added experience. The essential principles of design must be well understood. The relations of the different departments, questions of economical production, relative as well as absolute, must be studied. The managing engineer must be qualified to organise, and control the work of each department, leaving, however, details to the foremen or under-managers.

Mechanical Powers.—The most complicated machine may be regarded as a contrivance which, receiving force at one point, exerts it at another point, but modified in intensity and direction. Thus we have the most elementary types of machines in the time-honoured classification of the mechanical powers—the lever, the inclined plane, the pulley, the wheel and axle, the wedge and the screw.

Mechanical Stokers. — Machine stokers are classed under two types, the *coking*, and *sprinkling* respectively. In the first the fuel is fed on to the dead plate and carried forward by movable bars, the rate of progression of which is adapted to the rate of combustion. In the second the fuel is strewn over the firebars by some suitable arrangement, as by means of an automatic shovel operated by springs, with or without movable bars. In each system it is claimed that the combustion of the fuel is practically perfect before it reaches the farther end of the grate, and that nothing is left there to fall into the ash-pit but ashes and clinkers. Steam blast is often provided to create a draught, and to assist in keeping the bars clean. The blast is discharged from a tube carried along horizontally in front of the furnace and pierced with a number of small holes opposite the bar spaces. The steam can be shut off and the draught stopped if the steam pressure in the boiler requires to be lowered.

In all hand-firing, however carefully done, there is some waste of heat going out of the chimney—some unconsumed oxygen, some black smoke—unburnt carbon. There is sometimes a deficiency, or an excess of air supply, and too much or too little fuel. In the first case the gases are insufficiently burnt, in the second much oxygen goes into the chimney without having done any work in burning the carbon. In machine-stoking there is almost complete combustion, and little waste. But beyond this, and much more important, is the fact that good coal only can be used in hand-firing, while slack can be utilised in machine-

stoking, and will yield as high an evaporative duty as the better coal. Another item is that of the economy of labour. In a single boiler the fuel has to be fed into the hopper over the furnace by hand, and no economy in labour can be effected. But when several adjacent boilers are in use then their hoppers can all be fed automatically by means of elevators driven from a line of shafting. The fuel is raised to the level of the hoppers of machine stokers by means of an elevator, and carried along by some form of conveyor. The same shaft which works the stoker can work the elevator and conveyor.

Summed up; the advantages of machine over hand-stoking are:—Smoke prevention, the gases being consumed in the furnace. Economy of fuel, little or none being left unburnt, and inferior cheap fuel giving evaporation duty as high or nearly as high as the best fuel when hand fed. Economy of labour, in the case chiefly of a range of several boilers.

The fire-grate of a Cornish or Lancashire boiler terminates at the bridge. In a fire-grate fed from a mechanical stoker with movable fire-bars, it terminates several inches short of the bridge. The reason of the difference is this: In the first case, clinkering is performed by hand, the clinkers being raked out once or twice a day through the furnace door. In the second, the fire-bars being movable are self-cleaning, the clinkers being gradually carried forward by the fire-bars, and finally thrown over at the termination of the bars into the bottom of the flue, whence they are drawn out with a long scoop.

There are two other points of difference in the grate arrangements in hand-fired boilers, and those fitted with mechanical stokers. One relates to the length, the other to the spacing of the bars. The bars in hand-fired boilers are made either in two, or in three lengths. In those fitted with movable bars, the latter are made in one length only. In hand-fired boilers the air spaces are wider than those used with mechanical stokers, the latter being narrow, because small coal or slack is used.

To burn the gases liberated during combustion, the essential is to have a green fire, and a bright fire in the same grate. There are two methods of effecting this. One is, as in a Lancashire or Cornish boiler, to coke the fuel on the dead plate, so maintaining a green fire at the front of the boiler, and to keep a hot clear fire beyond towards the bridge. Then the gases liberated at the front become burnt at the back. The other is, as in locomotive boilers, to fire on alternate sides, keeping a green fire and a hot fire on each side alternately. In the hands of stokers who know their work these methods are efficient and economical. The mechanical stoker effects the same results. In the coking stokers there is a green fire on the dead plate, and a hot fire beyond. In the sprinkler stokers the green fire, though spread over larger areas, becomes a bright fire almost immediately.

James Watt invented a stoker in 1785, which could hardly be termed mechanical, since it was worked by hand. But the idea was to secure perfect combustion by passing the smoke from the fresh fuel through, over, or among a body of hot glowing coals. There were two sets of bars, one behind another. In Dowson's stoker, invented in 1816, the fuel was fed upwards by means of a piston. Upon this system about thirty patents have been based, though it is scarcely used now. The coking type of stoker was introduced by Brunton in 1822, and applied to externally-fired boilers. He included pushers for feeding, and also movable bars. More than two hundred specifications for coking machines have followed Brunton's, one of the best known being that of Jucke's, in 1841. The latter, though applied for a good while to externally-fired boilers, has not held its place when applied to boilers internally-fired. In the same year, 1822, in which Brunton invented the coking stoker, Stanley invented the sprinkler stoker. So that the two systems started together. The original stoker was applied to the wagon boiler. The fuel was thrown upon the fire by three vanes fixed on a shaft revolving in a case under the hopper. The original form, though much used for externally-fired boilers, was not well adapted to the internally-fired types which have come subsequently into use. In the hands of Dilwyn Smith, Henderson, Bennis, Proctor, and others, the original sprinkler stoker has been modified and adapted

to the internally-fired boilers. Mr Bennis combined the movable self-cleaning bars with the sprinkler system, and introduced mechanism for distributing the fuel over various parts of the grate area in succession, and included the use of a steam jet.

Objection has been made to mechanical stokers on the ground that their action is regular, while the duty required of many boilers, notably those working electric lighting stations, is very variable at short intervals of time. Mr Bennis has therefore made a steam regulator which answers effectually. When the duty falls off, the damper is partially closed, and the machine is stopped. When the duty rises, the damper is opened, and the machine restarted. The regulator acts as follows:—When the maximum pressure to which the boiler can be worked is reached, the maximum steam pressure lifts a safety-valve—causing a column of steam at maximum boiler pressure to run down a pipe, raising a bellows, partially closing the damper, and throwing the belt which drives the machine stoker on to the loose pulley, and turning off the steam jets under the fire-bars. When the pressure falls below the maximum, the reverse of these operations takes place; owing to the closing of the safety-valve the whole apparatus setting to work again. Mr Bennis states that when 40 per cent. of the power is thrown on or off, the steam pressure will not vary more than about 3 lb.

Messrs T. & T. Vicars' mechanical stoker is of the coking kind, having little resemblance to its prototype invented by Brunton in 1822. The fuel falls by gravity from a hopper into boxes, whence it is pushed on to the dead plate by means of plungers reciprocating alternately, and actuated by a cam shaft similar to that which moves the fire-bars. The fuel is coked upon the dead plate, and is then worked on to the fire-bars. Without describing the details of the mechanism used for the purpose, it will suffice to say that the bars receive an alternate or intermittent motion to and fro, simultaneously forward, but backward in sections. This has the effect of carrying the fuel forward, and of keeping the bars clean. The mechanism can be adjusted to various rates of motion, the driving power being supplied through a shaft which carries eccentrics, each of which actuates ratchet wheels and pawls, which in turn communicate the desired rate of movement to the bars and plunger shafts, such rate being separately controllable in each instance; and can be varied in each flue, as the machine for each flue is complete in itself. The driving shaft makes from eighteen to twenty revolutions per minute. The ash, clinker, and unconsumed fuel is thrust over the ends of the bars, forming a bank in the bottom of the flue, and this prevents the admission of cold air into the combustion chamber beyond. The refuse is drawn out at the front end at intervals of a few hours. The whole of this apparatus is carried upon girders on the ground in front of the boiler, which is better than being fastened to the boiler front, but the machine is so arranged that it can be moved with the boiler as the latter expands and contracts.

In the Bennis stoker, Fig. 191, the weight of fuel pushed over is regulated by means of an adjustable cam on the driving shaft, by turning a hand nut. The rate of feed can be seen by noting the position of the cam, and the rate can be regulated from nothing to 1 ton per hour. An angular shovel is used which scatters the fuel over different parts of the grate. This is actuated by a patent pneumatic gear. It comprises a coiled spring within a cylinder, pressing on a piston which propels the shovel. An air cushion takes up shock. The cam which draws back the shovel has four lifts, which distribute the fuel in four divisions, each being about 18 in. long, so that in a furnace with a 6 feet length of grate the fuel is thrown on only a quarter of the fire at once, which conduces to smoke consumption. The bars are self-cleaning, thus:—Tubular fire-troughs are made, Fig. 191, of the same length as the grate. The upper surface of each fire-trough consists of small interlocking grate bars, in lengths of about 2 feet, and the fire rests on these. The fire-troughs all move into the fire together for about 2 in., and are then drawn out by means of 4-in. cams on a transverse shaft, Fig. 191. These cams are of the same width as the troughs, so that they are scarcely subject to wear. Each tubular fire-trough has its own

supply of air, fed by a minute steam jet, so that the draught is distributed evenly over the whole of the fire-grate. The bars have extremely fine air spaces, to burn breeze, or dust. The fire never reaches the tubular fire-troughs, and the bars only have to be renewed. Wear of the cams is taken up by chilled wedge wearing pieces. A single set of bars runs the whole length of the furnace, being about 5 ft. long. Immediately within the furnace there is a depression in the bars of about 3 in. in depth. Beyond this they slope upwards again 3 in. in a length of 12 in. Afterwards they slope upwards 1 in 48 for the greater portion of their length, until at about the last 12 in., where they slope upwards 1 in 6. The object is to give the fuel ample time for complete combustion. The fuel is fed forward by the forward travel of the bars ($1\frac{1}{2}$ in.), their movement being effected by means of the cam shaft already mentioned. They are brought back 1 in 8 at a time. The ash and clinker falls over the ends of the bars into the flue, whence it is drawn out from the front of the boiler. The Bennis stoker will consume 56 lb. of small

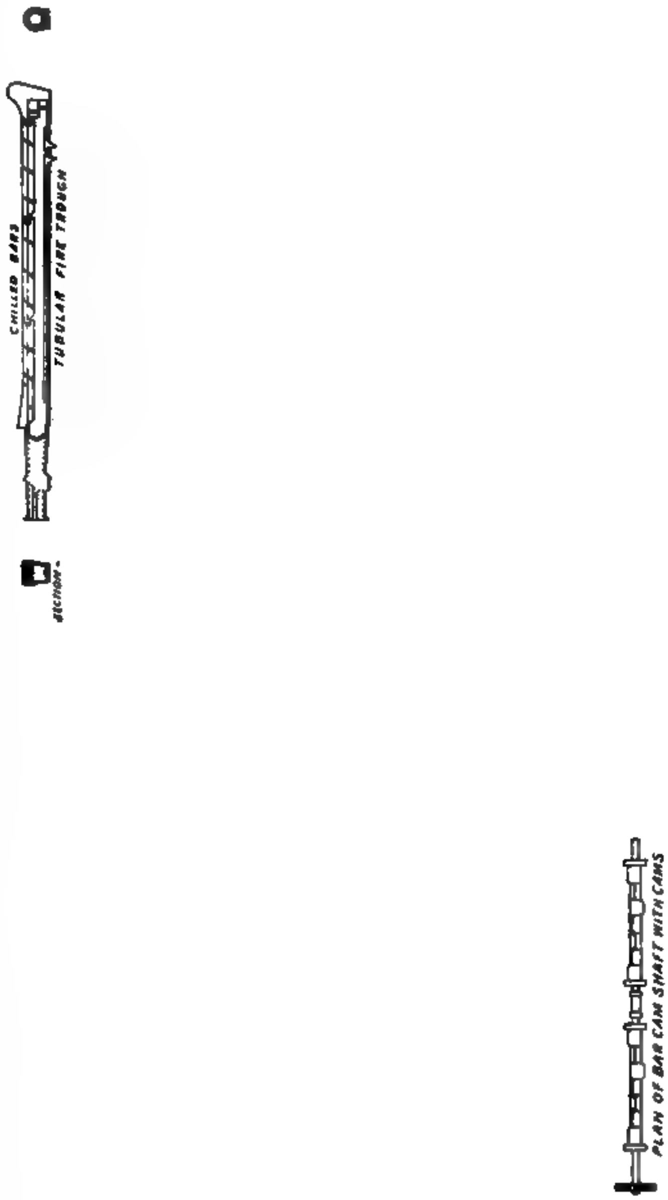


Fig. 191.—Bennis Stoker.

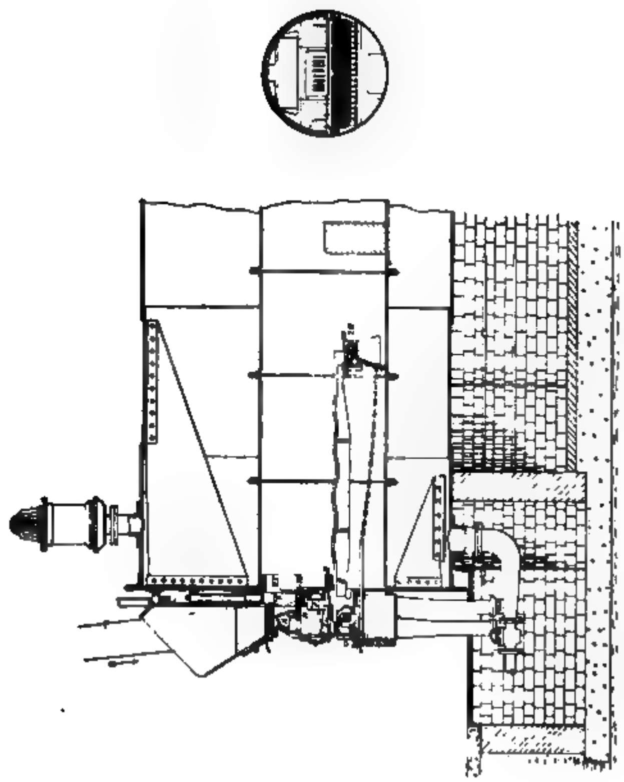


Fig. 102.—Meldrum Coking Stoker.

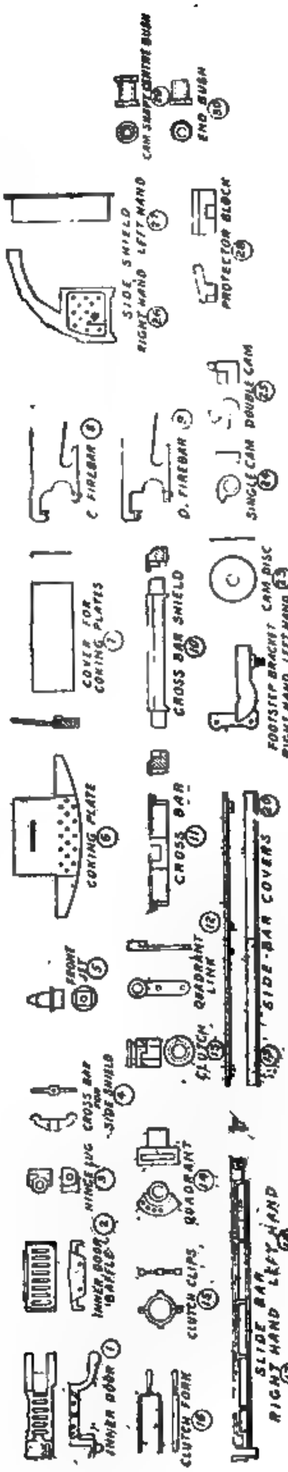


Fig. 103.—Parts of Meldrum Stoker

coal per square foot of grate area per hour regularly. With this stoker as good results have been obtained with small North-country coal as with the best Welsh coal when hand-fired. As the small coal costs only about half as much as the Welsh, the difference in economy amounts to 50 per cent. A 6-in. cylinder engine will work the machine stokers for a range of twelve Lancashire boilers.

From an experiment made by Mr Bennis as to the loss of steam in the grate jets of a mechanical stoker, it was found that at 82 lb. pressure the loss through sixteen holes, each $\frac{1}{32}$ in. in diameter, was 35 lb. per hour. This would mean a charge of about 2 per cent. on the boiler fuel.

Messrs Meldrum Bros., Ltd., make both coking and sprinkler types of stokers. Fig. 192 shows the first-named, as fitted to a Lancashire boiler, and Fig. 193 is a key to the separate parts, similarly numbered to those in the general drawing. The ram below the hopper is a sector working on a pivot instead of being flat to

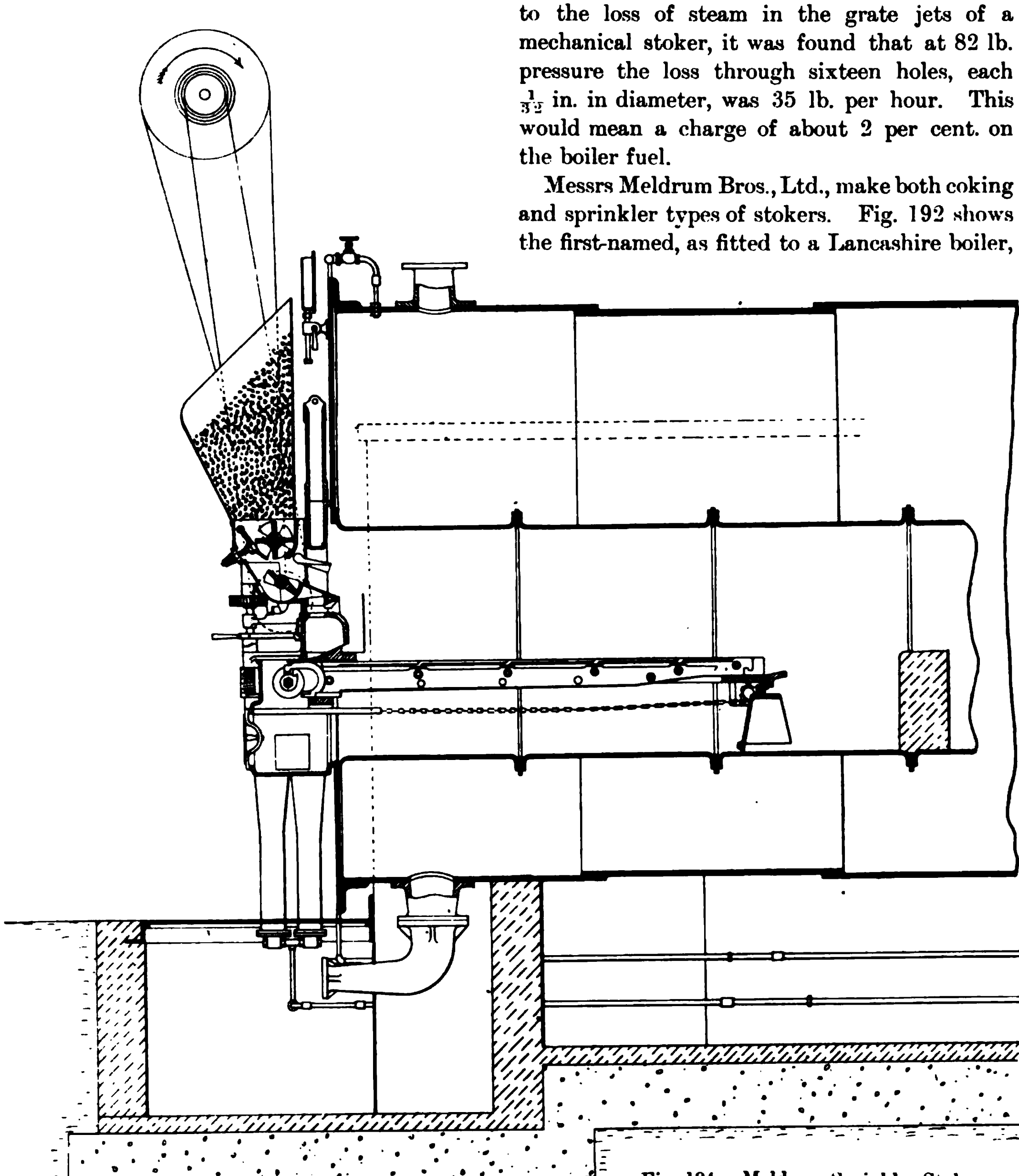


Fig. 194.—Meldrum Sprinkler Stoker.

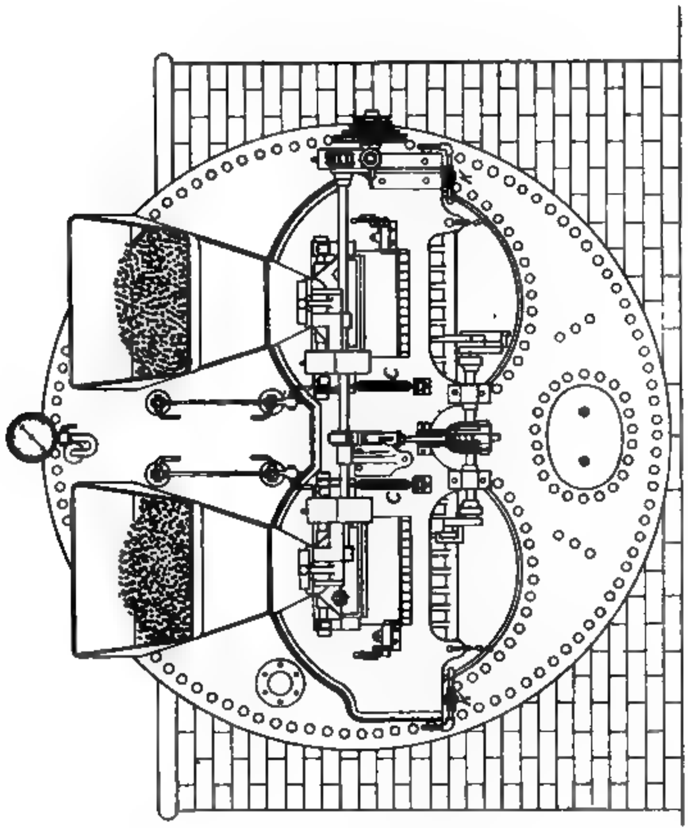
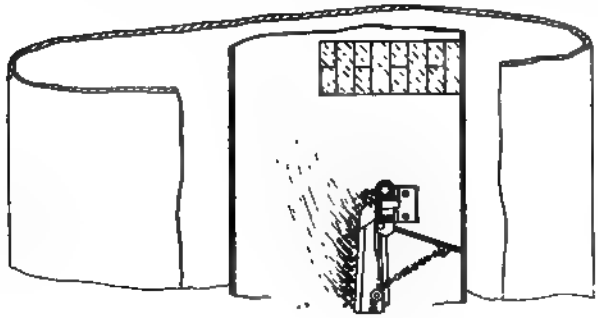


Fig. 193.—Proctor's Mechanical Stoker. (James Proctor, Ltd.)



slide horizontally. The rate of feed can be regulated without stopping the mechanism. The operating cams are carried on a hexagon shaft, and are chilled on the face. The fire-bars have undulating surfaces, so that the reciprocating action of adjacent bars prevents the clinker from adhering, and keeps the spaces free. The spacing is very narrow to utilise breeze and dust. The stoker may be combined with Meldrum's forced draught, so that the air pressure can be regulated to suit varying conditions, without depending on chimney draught. The furnace fronts are hollow, and the blast circulating through them, the fronts are kept cool and the blast is heated. The blowers use superheated steam.

Meldrum's sprinkler stoker as applied to a Lancashire boiler is shown in Fig. 194. It should be understood, however, that the sprinkler and the coking type are equally applicable to almost any class of boiler. In the sprinkler the fuel is dropped in measured quantities by a slowly revolving four-vaned measurer, and is immediately thrown on to the grate by a two-vaned high velocity fan. The fan and the measurer are clearly shown in the longitudinal sections. The coal is correctly distributed over the grate by the aid of moving

deflector plates which vary the trajectory. A stationary grate may be used with this type of stoker, though the illustration shows exactly the same type as would be used with the *Koker*, Fig. 192, *i.e.*, a moving grate. With a sprinkler stoker the moving grate serves to remove the clinker to the clinker pit. For moderate duty this machine is supplied without the forced draught equipment.

Proctor's mechanical stoker, Fig. 195, is of the shovel type, combined with movable fire-bars. The idea is to imitate the action of good hand stoking by distributing a small quantity of coal at brief intervals over the different parts of the fire. In Fig. 195, A is the shovel, which is of a vee shape in cross section, to throw the coal well up to the sides of the furnaces. It is actuated by a tappet wheel B, having three throws, and springs C. To cover the entire length of the fire-grate the tappets are placed at different distances from the centre, so giving different traverses to the shovel, and varying the tension put on the springs. The quantity of coal to be burnt can be regulated by adjusting the regulating screw D of the ram E, which supplies coal from the hopper above to the shovel below. It can be made to feed from 2 cwt. per hour upwards. The grate bars F are rocked to and fro by the mechanism shown, derived from an eccentric G, and rod, the ratchet wheel H, and dog to the lever J, and its connections. Steam is supplied to the fires through the cocks K, K, and piping L, which goes back to the hollow bridge at the rear of the furnace, and thence to the jet pipe M at the front.

The Underfeed Stoker.—This is a very successful type, of which over 4,000 are now in work. Obviously it avoids all risk of imperfect combustion, and consequent smoke, for instead of throwing green coal on top of a fire it brings coal already coked up on the grate. The sectional view, Fig. 196, shows the arrangement employed for internally-fired boilers. Fuel from the hopper enters the *retort*, or fuel magazine A below, the length of which is occupied by a worm conveyor driven by a small steam motor in front of the hopper. The fuel is thus carried along, and overflows in a convex mound upon the grate bars. The coal begins to ignite before it overflows, and the gases passing through the glowing coke are consumed without producing smoke. The fixed carbon of the coal is consumed by the air brought in through the tuyeres B, B, from the wind-box C, and through the apertures between the grate bars D. These

Fig. 196.—Underfeed Stoker. (Underfeed Stoker Co., Ltd.)

are arranged in the form of a terrace. The air spaces *a* are arranged horizontally to prevent the entrance of ashes and unconsumed coal into the wind-box below the grate.

The underfeed stoker is fitted to marine boilers with some variations in the design illustrated. In another form it is applied to water-tube boilers, and to steel melting furnaces. Fig. 197 shows this design in half-front elevation, and half-vertical section; and Fig. 198 in vertical longitudinal section. The action is as follows:—The fuel being brought into the hopper A, is conveyed

underneath the fire by a reciprocating sliding bottom B, which is actuated by a steam motor back end, and at the same time accumulating, it rises along the full length of the trough,

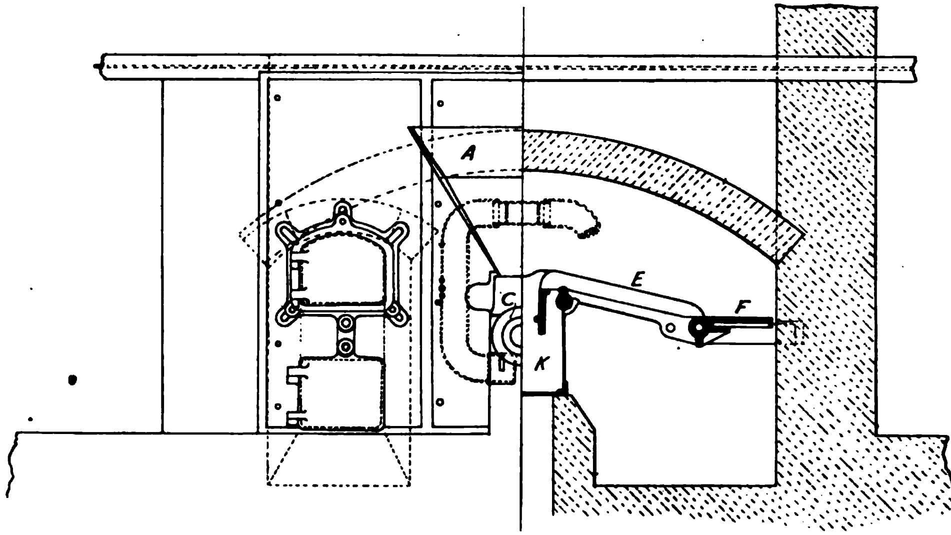


Fig. 197.—Underfeed Stoker.

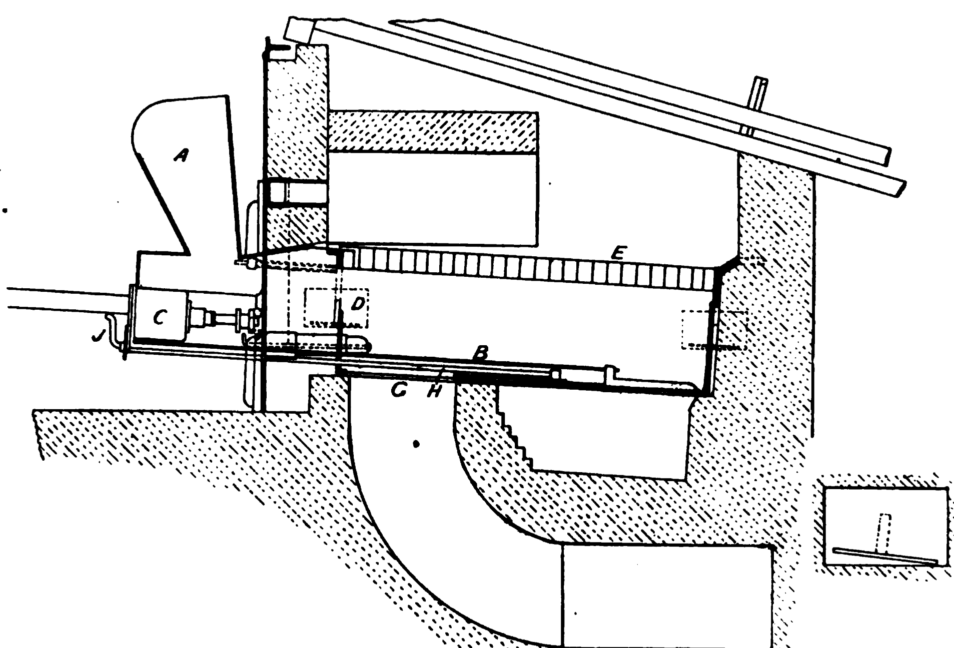


Fig. 198.—Underfeed Stoker.

C. A block D has the same sliding movement as C and B. The fuel is thus carried to the which becomes a coking retort. Rising in the trough it overflows on the transverse

grate bars E. These are alternately moving and fixed, the amount of movement ranging from ½ in. to 1 in., depending on the size of the furnace. The clinker is deposited at the sides of the furnace on the plates F. The air enters the stoker through the opening G, of which H is the wind-gate, the latter being adjustable by a crank J outside the furnace. The air entering the wind-box K passes into the retort.

Mechanics.—Broadly speaking, the science of mechanics is concerned with the action of force on matter—solid, liquid, and gaseous. This wide subject is divided into kinematics and dynamics, the former treating of motion, but not of the forces causing that motion, and the latter the investigation of the motion of a body and the force producing it. Dynamics is further divided into two branches—kinetics, treating of the action of forces in producing motion, and statics, dealing with bodies in equilibrium. Hydrostatics and hydraulics deal with liquids, the former embracing problems concerning their equilibrium, the latter dealing with their flow. The broad outlines of most of these subjects are dealt with under their special heads.

Melinite.—Is an explosive used in the French army. It is prepared from picric acid like lyddite, but the details of its composition and preparation are a Government secret.

Melting Point.—The melting point of any substance is that temperature at which it changes from the solid to the liquid state. This temperature varies widely for various substances but is constant for the same substance. In some solids the change is sudden and well marked, as in ice for example, in others it is gradual, and an intermediate plastic stage is observed.

The effect of pressure on substances whose volume increases on melting (and this includes the majority of solids) is to raise the melting point, and to lower this point in those substances that decrease in volume on melting, like ice.

The following are the melting points of the chief metals and alloys. The melting points at high temperature are only approximate.

Substance.	Melting Point. Cent.	Fahr.
Antimony	430	806
Bismuth	267	513
Brass	1,015	1,860
Bronze	900	1,652
Copper	1,100	2,012
Gold	1,100	2,012
Iron, cast	1,276	2,350
Iron, wrought	1,982	3,600
Lead	325	617
Manganese	1,245	2,633
Nickel	1,600	2,912
Platinum	1,800	3,272
Silver	962	1,763
Steel	1,760	3,200
Tin	228	442
Zinc	415	779

The fusibility of metals is of chief concern in the foundry. The colour of a heated metal as it changes from dull red to dazzling white gives a rough indication of its temperature.

Temperature. Cent.	Fahr.	Colour.
525	977	Incipient red heat.
700	1,292	Dull red.
800	1,472	Incipient cherry red.
900	1,652	Cherry red.
1,000	1,832	Bright cherry red.
1,100	2,012	Deep orange.
1,200	2,192	Bright orange.
1,300	2,372	White.
1,400	2,552	Bright white.
1,500	2,732	Dazzling white.

Mending up.—Repairing broken sand in moulds. It is done by hand with the trowel, and with cleaners and smoothers. Badly damaged sections have to be strengthened with nails, or with rods wetted with clay wash. The guide for mending up is often the pattern itself, or a portion of the same put back into the mould. In other cases a strip, or a sweep of wood of the proper contour is used, or a piece of sheet lead bent, or a boss, or print, or whatever happens to be most suitable or ready to hand. If much fresh sand is added and rods or nails wetted to secure it, skin drying of the fresh portions is generally done in green sand, using a heater or devil. In dried sand and loam, mending up is done before the moulds are put into the drying

stove. One of the advantages of plate moulding and of machine moulding is that the risk of broken moulds is lessened, with lessening of the amount of mending up required, and therefore the castings do not vary sensibly in dimensions and shapes.

Mensuration.—*See* **Areas, Arc, Circle, Cone, Cube, Cylinder, Parallelogram, Polygon, Prism, Pyramid, Ring, Sphere, Timber Measurement, Triangle, Wedge.**

Merchant Bars, or **Merchant Iron.**—The lowest quality of bar iron, or No. 2. It is produced by cutting up puddled bar, reheating, and rolling.

Merchant Mill.—A bar mill used for the production of rounds and squares of the smaller dimensions such as are kept in stock by iron and steel merchants. The term is also given to mills rolling small sections of tees and angles.

Mercury (Hg. 200).—Mercury or quicksilver is remarkable as being the only metal which is liquid at the ordinary temperature. Its freezing point is $-40°$ Cent., and boiling point 357° Cent.; sp. gr., 13·6. It occurs in the native state, but commercially it is chiefly obtained by roasting the ore, HgS (mercuric sulphide or cinnabar). The sulphur is oxidised, and the mercury vapour is condensed, $HgS + O_2 = Hg + SO_2$. The most important compounds are mercuric chloride or corrosive sublimate, $HgCl_2$ (a powerful poison), obtained by heating equal parts of the sulphate $HgSO_4$ and common salt, NaCl; $HgSO_4 + 2NaCl = Na_2SO_4 + HgCl_2$; mercuric oxide, HgO, prepared by heating the nitrate, $Hg(NO_3)_2$; the sulphide, which is found native; mercurous chloride, or calomel, Hg_2Cl_2, obtained by mixing and heating metallic mercury and corrosive sublimate in the proportion of three and four parts respectively. Mercury is alloyed with other metals (except iron and platinum), and then called an **Amalgam**.

Its great density, its fluid form through such a wide range of temperature, and its low specific heat, render mercury extremely valuable for scientific purposes. It is owing to these properties that it is used for measuring the temperature of the air in the thermometer, and the weight or pressure of the air in the barometer. For high pressures, as in steam boilers, the mercurial gauge is insufficient, and has long since given place to spring or dial gauges. Mercury is also used for extracting gold and silver from their ores.

A cubic foot of mercury weighs 848·7 lb.; a cubic inch ·4894 lb.: its specific heat = ·032; coefficient of expansion by heat = ·000099; latent heat of fusion = 5·1.

Mercury-Vapour Lamp.—An electric lamp, Fig. 199, Plate XIII., in which the illumination is derived from the incandescence of vapour given off by mercury heated by an electric arc.

The lamp consists of a long straight or curled glass tube containing a small quantity of mercury. Leading-in wires are sealed into the ends of the tube, which is then exhausted to a high degree with a vacuum pump and hermetically sealed. The wires being connected to an electric circuit, the lamp is started by tilting the tube so that the mercury flows to make a connection between them. An arc is then formed at the point of contact, and the mercury gives off a vapour which continues forming until the tube is filled, whereupon the tube is tilted back and the vapour forms a conducting path between the electrodes. This vapour becomes highly luminous and the lamp will continue in operation so long as the current is kept on. The light emitted is of a peculiar nature. Viewed closely it appears as brilliant white, but at a distance from the lamp has a bluish tinge. Owing to the entire absence of red rays, whilst black and white objects are unaffected, blue, green, and yellow are intensified, and red appears black or dark purple. As it is the presence of the red rays in artificial light which causes fatigue and strain of the eyes, the mercury-vapour lamp is found to be very suitable for use where close and continuous application to the work lighted is necessary. It is also particularly effective where the natural lighting has to be supplemented, as in badly-lighted offices, basements, &c.

The light is more equally diffused over a large area than with carbon filament or arc lamps, no shadows are thrown, and the long glowing tube of light is not so dazzling and

distressing to the eyes as the intensely brilliant spot of the arc lamp. Thus obscured globes are not required, and the 60 to 80 per cent. of the light usually wasted in that way is available for illumination.

The mercury-vapour lamp is very efficient, requiring only ·5 watt per spherical candle-power, against 1½ to 2 watts for the arc, and 3 to 4 watts for the carbon-filament glow lamp. Roughly, a mercury lamp may displace four 32 candle-power glow lamps, and will give 700 candle-power against 128 candle-power for an equal consumption of power, or in place of eighteen 16 candle-power glow lamps, will give twice the light at one-third of the power equally diffused over the same area, also remaining efficient for a greater length of time. Its average life equals 2,000 hours.

Metacentre.—A floating body is kept in equilibrium by two forces, the weight of the body acting vertically downwards through its centre of gravity as at G in Fig. 200 (1), and the upward thrust of the water acting through the centre of gravity of the displaced liquid as at F. F is called the centre of buoyancy, and the upward thrust acting through it is the resultant of the upward and parallel pressures of the water. If the body is in equilibrium these two forces are equal and opposite, and the line joining the two points through which they act is vertical. It is called the axis of flotation. If the body be disturbed from its position of equilibrium, Fig. 200 (2), the point F representing the centre of gravity of the displaced liquid changes its position, and, as indicated in the diagram, a couple is produced. The rotation set up may right the body, or overturn it according to the position of the point M where the vertical line from the new centre of buoyancy cuts the axis. This point is called the metacentre.

In Fig. 200 (2) M is above G, and the floating body will right itself. This is a case of stable equilibrium. But when M is at a point in the axis below G, Fig. 200 (3), the body will not be restored to its former position, and the axis will depart more and more from the vertical. This is an example of unstable equilibrium. In shipbuilding a highly important problem is that of getting the metacentre as high as possible above the centre of gravity of the body, and the purpose of ballast in any form is to bring the latter point as low down as possible. In bodies of certain shape such as a sphere, or a cylinder floating with its longitudinal axis horizontal, the points G and F remain in the same vertical line no matter how the body is disturbed. Such a body is in neutral or indifferent equilibrium.

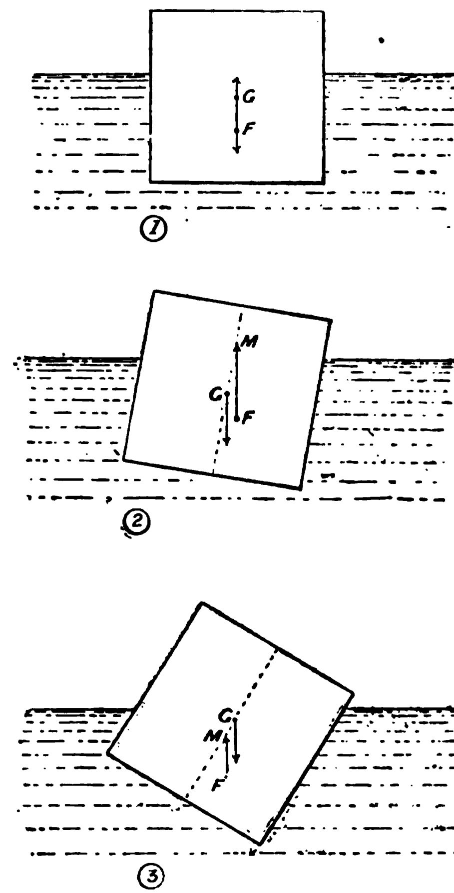


Fig. 200.—The Metacentre.

Metallic Packings.—These have come into extensive use as steam pressures have increased. The old hemp packings (*see* **Packings**) will not withstand the heat of high pressure and superheated steam. The metallic packings, though costly, have a very long life, by comparison. But this is not their only advantage, as the following paragraphs will show.

A packing which has a good record is one invented by Mr E. P. Monroe, and known

commercially as the United States metallic packing, though it is manufactured at the

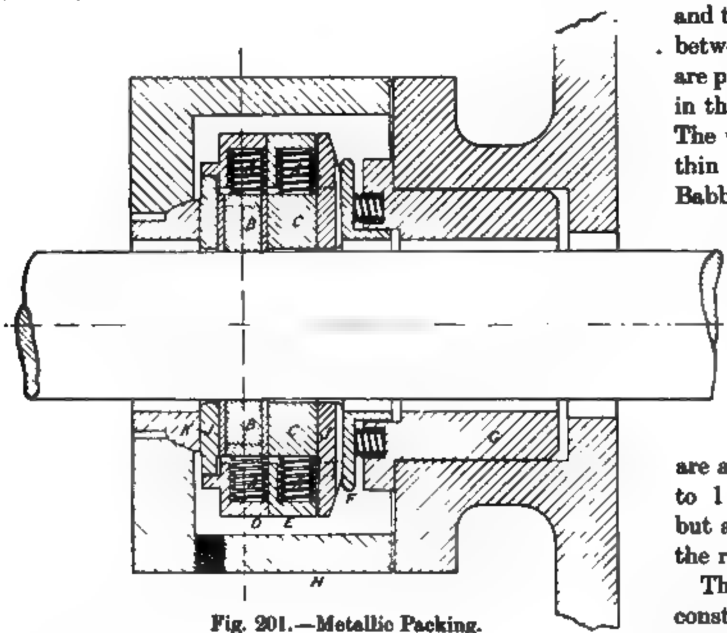


Fig. 201.—Metallic Packing.

Soho Works, Bradford. It avoids the undesirable features of those packings which depend for their tightness on the screwing down of a gland, the result being an unknown pressure, and which is usually much in excess of that which is desirable in order to ensure tightness. This increases friction and causes scoring of the rods. It seems unmechanical to obtain the lateral pressure required by endlong pressure. Neither does the latter permit of variation in pressure such as in an ideal packing would be produced at any range between initial pressure and vacuum.

Figs. 201 and 202 illustrate the packing in longitudinal, and transverse sections. The first feature to be noted is the lateral springs A. These deliver a constant pressure which never exceeds $1\frac{1}{2}$ lb. to the square inch, and is less as the blocks diminish in size. The springs press against packing blocks B, C, and also feed the blocks B towards the shaft as they wear. The springs are held in pockets in rings which are disposed outside the packings. The sets of blocks B, and C, are put together in two sections, with four blocks to a section. Each section comprises two packing blocks, B, and two guide blocks, C. The joints between the blocks in one section are placed at right angles with those in the other section, to break joint. The working blocks B, consist of a thin case of gun-metal filled with Babbitt metal. C, C are guide blocks, and do not come into actual contact with the rod. The surface of each working block B, which is in contact with the rod is equal to about one-third the circumference of the latter. A feature of importance is that these blocks are always thin, ranging from $\frac{3}{4}$ in. to 1 in. in thickness. This gives but a small surface in contact with the rod, which is right in theory.

Though the springs exert a small constant pressure, this alone is not relied on to produce tightness. Increased pressure is produced by the steam, and in proportion to the pressure of the steam from

Fig. 202.—Metallic Packing.

initial to final pressure. The steam is free to enter the stuffing-box from the cylinder, a space

being left between the rod and the hole in the cover, and the rod only makes a close fit in the actual packing, an important point to be referred to again.

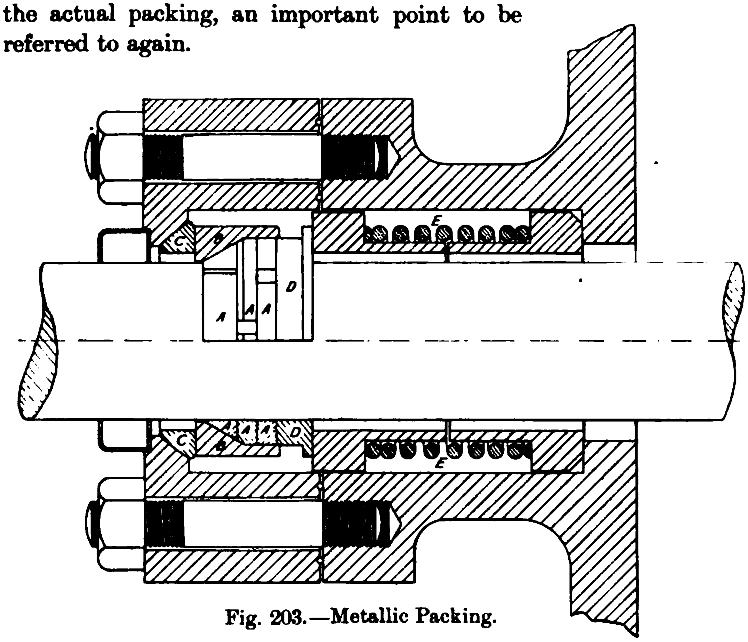


Fig. 203.—Metallic Packing.

The steam passes between the flange of the plate F, and the spring bush G, and being then confined by the casing H, it exerts pressure on the packing blocks B. Hence the pressure varies with the varying pressure in the cylinder. But the full force is not exercised on the piston rod, because the guide blocks C, receiving their portion of the pressure transmit it to the sides of the working or packing blocks B, and so check their movement.

Lateral motion is provided for thus: Plates J, J confine the rings D, E, in the pockets of which the springs are placed. On the outside of one plate, J, there is a ball, K, fitting a socket on a flange of the casing H. On the other side of the packing there are a number of follower springs in G, which are protected by the flanged plate F. Thus the packing may have a direct endlong movement between the plates J, J and the ball ring K, and the spring plate G. It may also have a rocking motion between the ball ring K, and the socket in the casing H. This ball joint is a most important feature, because it provides a flexible packing to follow rods that are not in alignment in consequence of wear.

A difference is made in the packings for condensing engines, the follower springs in G being made stronger. Collectively they produce a pressure of 16 lb. to the square inch on the ball joint, hence all the joints in the packing parallel with the piston will hold the vacuum.

These packings have a good record for dura-

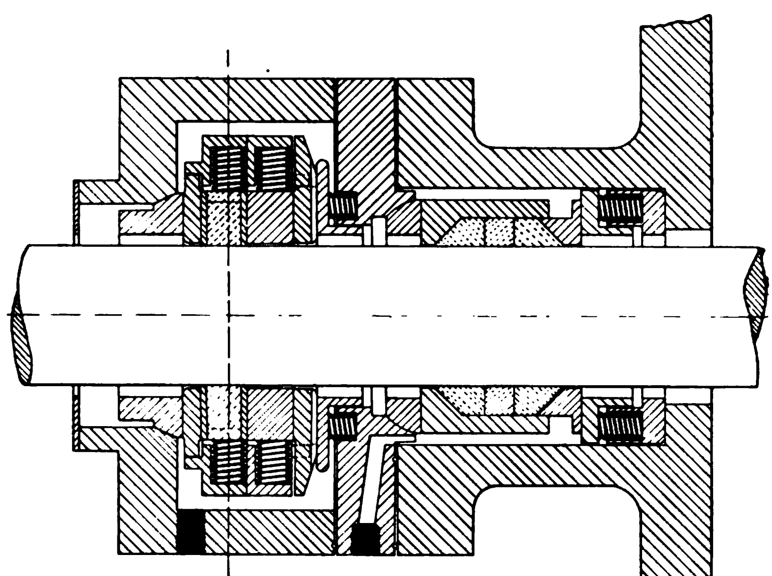


Fig. 204.—Metallic Packing.

bility. Many cases have occurred of packings lasting for from fifteen to twenty years without

any outlay for repairs. Locomotives have run for 118,000 miles without the packings being touched.

Modifications of this packing are effected to

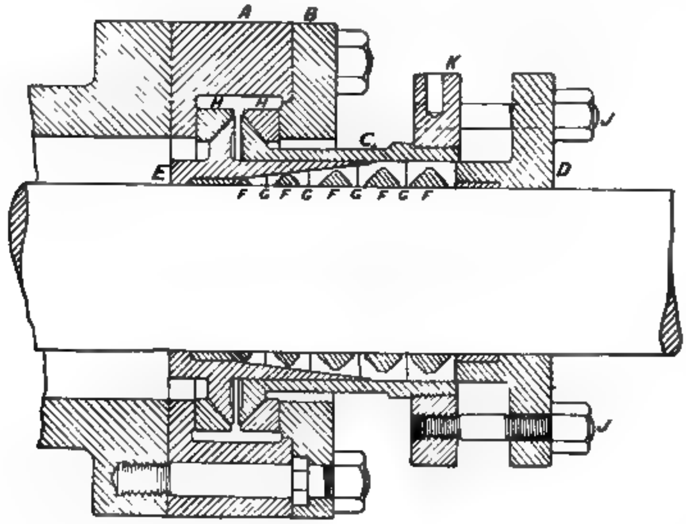


Fig. 205.—Metallic Packing.

suit varied conditions. One of these is adapted to oval flanged stuffing-boxes. It comprises, Fig. 203, three Babbitt rings, A, placed in a vibrating cup, B, the interior of which is partly conical. The cup rests against a ball and socket ring, C, the whole being kept in its place by a follower, D, and one or more springs, E. The latter press the ball ring against the socket in the head of the case, and form a steam-tight joint there. For high pressure superheated steam, another modified design is employed, Fig. 204. It is a combination of the packing first described with the cone packing of the second example.

The metallic packing by J. & E. Wood, is shown in one form in Fig. 205. Variations are those of details only. In Fig. 205, A with its cover B forms the casing for the actual stuffing-box, C. D and E fulfil the functions of glands, containing the packing between them. This comprises rings, F, of Babbitt metal, packed with asbestos packing G. The casing C and inner gland piece F are provided with spherical faces in contact with joint rings H, H; and the sliding movement thus provided for gives freedom for motion in all directions. The bolts J compress the packing, and exercise pressure against the joint rings H, H in opposite directions. The holes provided in the flange K of the stuffing-box are for the purpose of turning the box round the piston rod, and causing the joint rings H, H to rotate, which tends to equalisation of wear on the piston rods. This packing, it will be noted, is self-adjusting if rods are out of line.

The metallic packing of Messrs Lancaster & Tonge, Ltd., shown in section in Fig. 206, has a ring A, held within the stuffing-box by the cover. Another ring, B, fits A by ball faces, and two sets of sectional blocks, C, D, lined with Babbitt are pressed down by a ring E, with springs F. Encircling springs, *a*, *a*, *a*, *a*, cause the blocks

Fig. 206.—Metallic Packing. (Lancaster & Tonge, Ltd.)

C, D to embrace the rod; these springs, which are of spiral form, can be screwed together to grip more or less tightly.

Metalloids.—The name given to those elements which are non-metals. *See* **Chemistry** (Vol. III., p. 218). The term is also used to embrace certain elements with properties which are intermediate between the metals and non-metals.

Metal Patterns.—These are made in metal, because the large numbers required off them would soon play havoc with those of wood. Another and equally cogent reason in the case of the smaller patterns is that very often several of these exactly alike are contained in one box, and it is easier in such cases to make the duplicated patterns in metal than in wood. The methods of constructing metal patterns vary with the methods of moulding which are adopted. There are two classes of wood patterns, one being made for actual service, the other only to cast metal patterns from. The first are made from mahogany, or yellow pine, the second from common red deal, or whatever cheap wood happens to be available. The first are made and preserved with the greatest care, the second are thrown away when the metal patterns are cast. Neither is any particular trouble taken in regard to arrangements of grain, or of strength, or security and permanence of attachment of the several parts, but the job is just done in the cheapest and most expeditious manner. The wooden pattern has no permanent value, the metal pattern cast from it has.

These wooden patterns must have double allowance for shrinkage given, and also allowances for tooling, as turning, shaping, filing, boring, or other work necessary to give the smooth and true surfaces desirable. Again, metal patterns are mostly made solid when moulded in joint boards, but divided when put on plates, excepting of course in those cases where the mould goes wholly in the bottom box. These are the simplest cases of metal patterns. Often, however, several are cast together, and with or without their pattern runners. Several may be cast together for working on joint boards when the patterns are small, and of simple shapes. Thus screws and pins may be cast in a length. They may be cast with their runners for fastening to a plate, or they are frequently so cast in one with the plate.

Metal core boxes are as common as patterns of metal. Wooden boxes are made and cast from, and then trimmed to exact dimensions. As they are generally cast in a white metal this is not difficult, while the box is made sufficiently massive to retain its shape in service. The patterns are made in iron, brass, and gun-metal chiefly, though white metals are sometimes used for them.

In preparing metal patterns for joint boards they are made as wooden patterns are for the same method, namely solid. The boards are cut out so that the patterns shall drop into the recesses, until the joint planes are level with the face of the board. When patterns come in the bottom box only, they are simply laid on the face of the joint board by the moulder. Runners may be laid from the ingate to the several patterns, or they may be cut in the mould after ramming has been done.

For the fitting of patterns to plates, *see* **Machine Moulding,** and **Plate Moulding.**

Metals. — The elements are classified as metals and non-metals (*see* **Chemistry**), but the division is to some extent arbitrary. Though nearly sixty metals are known to the chemist many of them are extremely rare, and of the rest only a small fraction are used by the engineer.

As regards their occurrence, few are found in the free or native state—gold, silver, platinum, mercury, bismuth, copper, and occasionally iron. But the great majority occur as metallic ORES, either as veins in the earlier sedimentary rocks or in masses in later formations of sedimentary origin. Iron ore, the most important of all in engineering, belongs to the last-mentioned formation. Many are combined with oxygen and sulphur. Certain metals are found only in particular localities, and often in small quantities, and others are widely distributed, and abundant. Iron, for example, probably constitutes 6 per cent. of the earth's crust.

The metals possess certain physical characteristics in common :—

1. At ordinary temperatures they are all solid but mercury.

2. Except when pulverised they exhibit lustre. Arsenic, iodine, and carbon (in some forms) among the non-metals are likewise lustrous.

3. They all possess opacity in a high degree; some of the more malleable metals are translucent when beaten out into thin sheets.

4. All metals are good conductors of heat and electricity, silver taking the premier place. Copper is the next best conductor of heat and electricity, and then follow in order, gold, brass alloys, tin (though tin is a slightly better conductor of electricity than brass), iron, nickel, steel, lead, platinum, antimony, and bismuth. A metal which is a good conductor of heat is also a good conductor of electricity. Impurities considerably diminish the conductivity of a metal.

5. With the exception of silver, copper, and gold, their colour is generally a greyish white.

6. All are fusible, though melting points vary widely from $-39°$ Fahr. for mercury, to 2,850° to 3,300° Fahr. for cast steel. *See* **Melting Point**.

7. As regards weight, the metals vary through a wide range. The heaviest is osmium, the lightest is lithium. The specific gravities of certain metals are as follows (water = 1). Osmium, 22·5, platinum, 21·5, gold, 19·3, mercury, 13·59, lead, 11·4, silver, 10·5, bismuth, 9·8, copper, 8·82, nickel, 8·8, manganese, 8·0, iron, 7·9, tin, 7·29, zinc, 7·1, antimony, 6·7, aluminium, 2·56, magnesium, 1·74, lithium, ·58.

8. Malleability, ductility, tenacity, and brittleness, properties depending mostly on the degree of cohesion between the molecules, also vary considerably. Gold is the most ductile and malleable of metals; it is capable of being beaten out into sheets of which 200,000 superimposed would measure but an inch thick. Silver can be hammered into leaves $\frac{1}{1000}$ of an inch thick. The order in which the metals stand as regards malleability is:—Gold, silver, copper, tin, platinum, lead, zinc, iron, nickel; and as regards ductility, they stand in the following order:—Gold, silver, platinum, iron, nickel, copper, zinc, tin, lead. The malleability of a metal is affected both by temperature and the presence of impurities. Heating increases malleability in some cases, decreases it in others. Iron containing phosphorus is malleable when hot, brittle when cold, whereas the presence of sulphur reverses this state of affairs.

Metallurgy.—Is the study of the extraction of metals from their ores, and of the processes of preparation for their use in industrial arts.

Very few of the metals occur in the native state. The majority are mixed with other elements, and these compounds are called ores. Ores also are generally found mixed with earthy matter—the "matrix" or "gangue" consisting of quartz, silicates, lime, fluorides, sulphates, &c. The ores themselves are oxides, as Fe_2O_3 (hæmatite), SnO_2 (tin dioxide); carbonates, as $FeCO_3$ (iron carbonate or chalybite); silicates, as $PbOSiO_2$ (lead silicate); sulphides, as PbS (galena) and ZnS (blende); arsenides, as $CoAs_2$ (tin white cobalt). Most ores occur in veins, lodes, or in the early sedimentary rocks, iron being a notable exception, and it is thought that they were thus deposited from aqueous solution by some unknown agency—possibly chemical precipitation.

The percentage of pure metal contained in ores varies considerably. Iron ores with less than 30 per cent. of pure metal are discarded; magnetite contains 72 per cent. of iron, hæmatite 70 per cent., and the carbonates nearly 50 per cent. Blende contains between 40 and 60 per cent. of zinc. Copper ores are valuable even with less than 30 per cent. of pure metal. The "precious" metals, gold and silver, are, of course, rich with very small percentages of pure metal.

Partial separation of the ore from extraneous matter is obtained by the mechanical processes of crushing, sifting, and washing. Crushing is done in a rock breaker or stamp battery and the ore is then passed on to sizing apparatus. It is further mechanically separated from the useless gangue by the agency of water. The non-metallic portions being of less specific gravity than the ore, either float on the surface of water or sink more slowly than the heavier metalliferous matter. This process is also valuable when more than one metal is present, for each sinks according to its specific gravity.

In some cases ores undergo partial disintegration and oxidation by "weathering" or exposure to air, rain, and frost.

Volatile matters are got rid of by roasting or calcination, the weight of the ore being thus reduced to from half to three-quarters of the original amount. Roasting is performed in

enormous heaps when there is sufficient combustible material in the ore itself, as in the case of blackband ironstone. When fuel has to be added calcination in kilns is generally adopted. The Gjers kiln has a capacity of 400 to 700 tons.

The succeeding processes, all included under the general term smelting, vary considerably with the ores of different metals, and even with those of the same metal but of different chemical composition. If the ore is already an oxide, reduction (*i.e.*, isolation of the metal) is attained by heat alone or by the addition of some such reducing agent as carbon, carbon monoxide, hydrogen, hydrocarbons, or even metals as iron and manganese. These combine with the oxygen of the ore, and so release the pure metal. In many cases the preliminary process of roasting converts an ore into an oxide, the source of oxygen being the atmosphere. Some ores are more easily reduced when in the form of sulphides, arsenides, or chlorides, and such a compound is then artificially produced by heating with sulphur, arsenic, or chlorine. Such an artificial sulphide is called a regulus or matt, and an arsenide, a speise. The scorifying action of silicates is avoided by producing a sulphide.

Metals which are more or less volatile, such as mercury and zinc, are isolated from the ore by distillation. In the case of zinc, the ore is mixed with carbon, and the volatilised vapour passes into a condenser.

When ores contain more than one metal these are separated, as mixtures of liquids of different boiling points are separated, by fractional distillation. Temperature is raised above the melting point of one, but kept below that of the other metal. Argentiferous lead is separated from silver, and tin from iron and arsenic by this process, which is termed liquation. The same term is applied to the separation of one metal from others, even when it is not removed from the mass. *See* **Eutectic Alloy**.

Gold and silver (which do not oxidise) are obtained from their ores by cupellation, that is by oxidation of the base, and solution of the metals in molten lead. The process is so named from its being carried out in a cupel, a vessel made of bone-ash. The oxides are partly absorbed by the porous vessel. These two "noble" metals are also soluble in mercury, and are extracted by grinding the ore to a powder to which mercury is added. The amalgam is squeezed through canvas bags to eliminate any excess of mercury, the pasty compound remaining is heated, and the mercury volatilises.

Certain metals are extracted from their ores by first making a solution from which the metal is precipitated by reagents. This method is called a wet process as distinguished from the dry process in which reduction is obtained by high temperatures in furnaces.

Some of the more valuable metals are obtained by electro-chemical methods, an electric current being passed through the liquid in which they are present.

To withstand high temperatures, furnaces are lined with refractory materials. Of these the chief are silica in the form of bricks, alumina, lime, and magnesia. The fire-clays of the coal measures are hydrated aluminous silicates with lime, magnesia, &c. *See* **Fire-Clay**.

Other related subjects are dealt with under **Alloys, Blast, Blower, Blowing in, Chimney, Fuels, Slags,** and the various furnaces under their names.

Metal Mixer.—A vessel which receives iron of varying grades from the blast furnace, or the Bessemer cupola, to be subsequently transferred to the converter. This is alternative to taking the metal direct from the blast furnace to the converter. The advantage of the system lies in the fact that irons of irregular composition can be mixed, and irons from different blast furnaces be tapped, which is not practicable when direct casting is practised. The metal in the mixer remains fluid until filled, when a quantity sufficient for a blow is tapped into a ladle and taken to a converter, and the amount made good with fresh additions from the blast furnaces.

The early mixers resembled approximately in general outline the converters; Figs. 207 to 210 show more recent types. The photograph, Fig. 207, Plate XIV., shows a mixer of 750 tons capacity (which is of exceptionally large dimensions) made by Messrs Davy Bros., Ltd., for the Ebbw Vale Steel Company, and Figs. 208, 209 are detail drawings of the same. It

is a patent of Colonel Charles Allen, and Mr Charles Davy.

The body of the mixer is made of a double thickness of steel plating. It is carried on steel rockers A, of box section. They are machined on the undersides, where they rest on and rock on steel rollers B. The latter, which are 4 ft. coned and the cones terminate in cast-steel rings which are machined on the face. Tilting is effected by two hydraulic cylinders E, mounted on trunnions. They have sufficient stroke to empty the mixer if required, through the pouring spout F on the opposite side. Gas firing is provided for by the port ends G, G, to

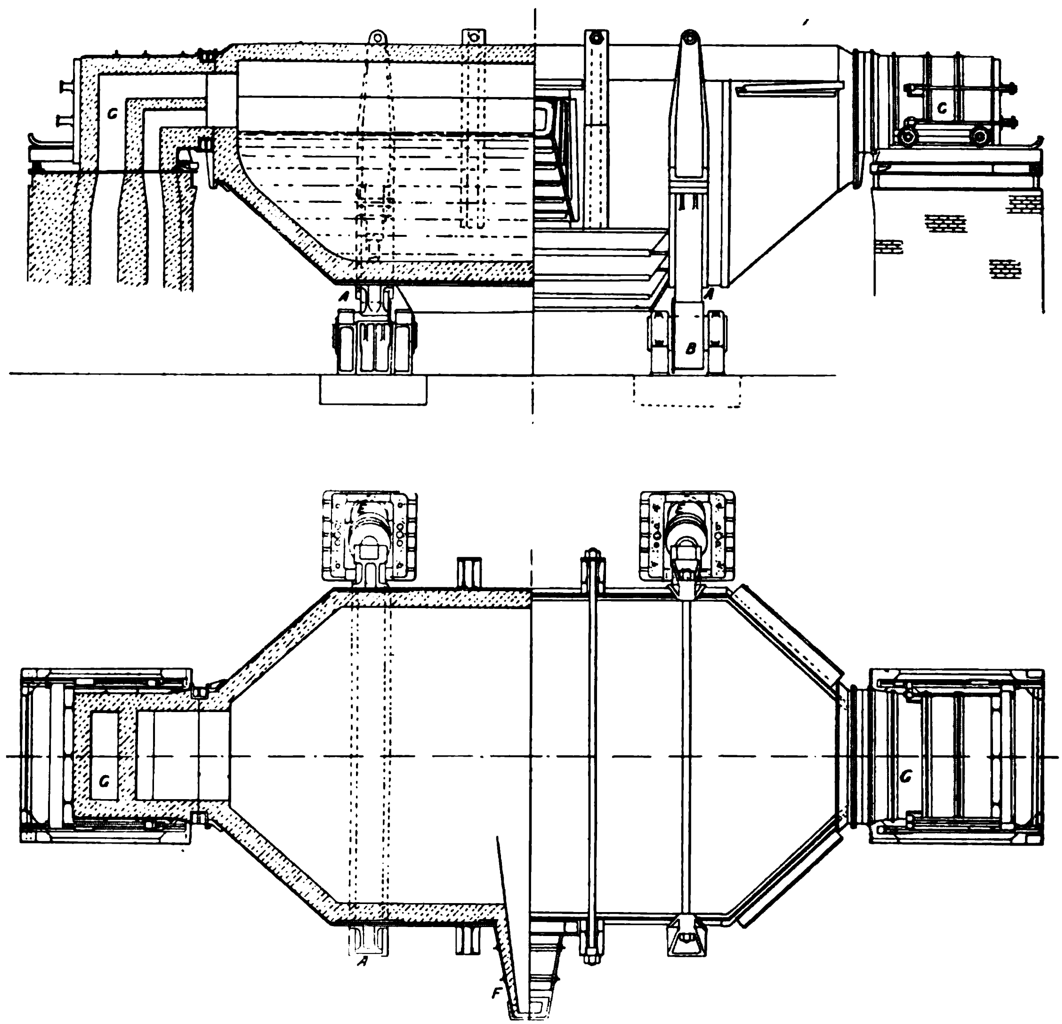


Fig. 208.—Metal Mixer.

6 in. in diameter, are turned, and mounted in bearings in cast-steel girders. The bottom of the mixer is stiffened by rolled steel joists C, to afford support against any tendency to bulge by the weight of the metal. The top is tied together by four 6-in. tie bolts. The ends are maintain the temperature of the metal. These ends are mounted on wheels so that they can be easily moved back when required.

Mixers are lined for acid or basic work. The one described is for acid lining. Fig. 210, Plate XIV., is one for basic steel. It is of 150

Fig. 207.—METAL MIXER, 750 TONS CAPACITY. (Davy Bros., Ltd.)

Fig. 210.—MIXER OF 150 TONS CAPACITY. (Davy Bros., Ltd.)

To face page 188.

tons capacity. Doors are provided on the sides of the body of the mixers, and on the coned ends, to render the whole of the lining easily accessible for inspection and filling. On the left-hand side of this photograph one of the gas-reversing valves is seen. In the centre is hydraulic gear for working them, and on the right-hand side the air-reversing valve. By means of these provisions metal can be retained in a molten condition for an indefinite period, or the temperature can be increased if desired. The more usual capacities of the mixers are 150 tons, 200, and 250 tons.

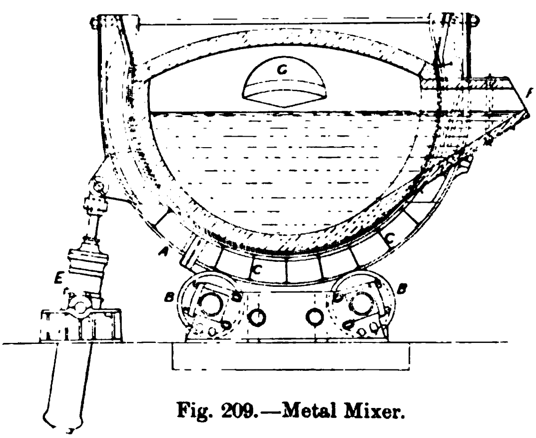


Fig. 209.—Metal Mixer.

Meter, Electric. — An instrument for measuring and registering the quantity of electricity delivered to motors, lamps, or other apparatus over a given time. The meter must record the watts rate of working, making its record to suit the fluctuations of the load, adding together the various times of duration, and providing an indication of the total watt-hours (watt × time) covered by the observation.

Thus, supposing a motor to be consuming on load

25 amps. at 500 volts for 1 hour,
then 30 „ „ 500 „ „ 2 hours,
then 40 „ „ 500 „ „ 4 „

it will be seen that the meter must register

(1) $25 \times 500 \times 1 = 12{,}500$ watt-hours.
(2) $30 \times 500 \times 2 = 30{,}000$ „
(3) $40 \times 500 \times 4 = 80{,}000$ „

A total of $\underline{122{,}500}$ watt-hours.

The meter is marked to read direct in B.T. Units (*see* **Kilowatt Hour**), so that the above would show that 122·5 units had been consumed in seven hours. Again, assuming that it is required to know what average load a motor is doing, this may be computed from the meter readings.

$$\frac{\text{B.T. Units registered}}{\cdot 746 \times \text{Time}} - \text{Inefficiency loss of motor} = \text{B.H.P. developed.}$$

The inefficiency losses (shown in the Test Certificate, which should always be obtained from the makers when a motor is purchased) should not be more, in a good motor, than 14 per cent., or on fluctuating loads, say, 20 per cent. average. Assuming the latter figure in the above case, then :—

$$\frac{122\cdot 5}{\cdot 746 \times 7} = 23\cdot 4 - 20 \text{ per cent.} = \begin{array}{r} 23\cdot 4 \\ 4\cdot 68 \\ \hline 18\cdot 72 \end{array}$$

average B.H.P. developed by the motor during the time of running.

An electricity meter is therefore useful for measuring the B.H.P. developed as well as the electricity consumed by electric motors. Meters are of various types, the choice depending upon the class of service required. Thus, whilst for low-pressure continuous current a cheap make on the electrolytic principle may be selected; for large power and higher pressures of direct current, a meter of the motor type, the electrically governed clock, or the mercury meter would be preferable.

Alternating currents require special meters, usually of the clock or motor type, and here the inductive or non-inductive character of the load must also be taken into account. The design of electricity meters has been brought to a high state of perfection.

Whilst it is not necessary for the engineer to have an expert knowledge of this very complicated subject, he may be advised in his selection of a suitable instrument that, for motors under say 10 H.P. an electrolytic meter is suitable up to 250 volts, and will give fairly accurate results. Above that the Ferranti mercury meter or the clock meter would be preferable. For a power station main switchboard one of the larger motor meters would be

required. There are, however, so many makes, suitable for all conditions, that he should have no difficulty in selecting one of a kind and price to suit the circumstances.

In every power-plant a main meter should be installed. The engineer will then be able to work out the amount and cost of the power generated, and see exactly the benefit accruing from any improvements which may be carried out from time to time in the economical application of the power generated.

Metre.—The unit of length in the metric system, and also the unit on which the entire metric system of weights and measures is based. A metre equals :—

39·370 inches.	3·280 feet.
1·093 yard.	·1988 pole.
·049 chain.	·0049 furlong.
·00062 mile.	

In the following table of equivalents the vulgar fractions are only approximately equivalent to decimals :—

			M.	Fur.	Yds.	Ft.	Ins.
Millimetre -	·0393	in.	...	...	...	...	$\frac{1}{25}$
Centimetre	·393	,,	...	...	...	$\frac{1}{30}$	...
Decimetre -	3·937	,,	...	...	...	$\frac{1}{3}$	...
Metre -	39·37	,,	...	...	1	0	3·37
Decametre -	32·8	ft.	...	...	10	2	9·70
Hectometre	109·36	yds.	...	...	109	1	1·07
Kilometre -	1093·633	,,	...	4	213	1	10·79
Myriametre	6·213	mls.	6	1	156	0	11·9

An idea of the smaller metric measurements may be gained from the statement that this page is 2·5 decimetres, or 25 centimetres, or 250 millimetres in length, and the letter "i" in "this" is 1 millimetre high.

Metric System.—This system of weights and measures was instituted in France, in 1801, and it is based on the metre, the length of a ten-millionth part of the quadrant of the meridian passing through France from Dunkirk to Formentera. It has since been found that the metre is $\frac{1}{163}$rd part of an inch short of the exact measurement. The system has been adopted by over twenty countries with a population of 483,000,000 people. Great Britain, the United States, and Russia still retain their national weights and measures, though here and in the States the metric system is permissible.

The superiority of the metric system consists in :—

(*a*) The simplicity of the multiples and sub-multiples.

(*b*) The relation between the various units.

The unit increases by successive multiples of ten, and decreases by successive subdivisions by ten. Thus the table of length will be :—

Metric Terms.	Proportion.
Millimetre - - -	$\frac{1}{1000}$
Centimetre - - -	$\frac{1}{100}$
Decimetre - - -	$\frac{1}{10}$
Metre - - - -	1
Decametre - - -	10
Hectometre - - -	100
Kilometre - - -	1,000
Myriametre - - -	10,000

The prefixes for the multiples, deca (ten), hecto (hundred), kilo (thousand), and myria (ten thousand), are Greek; those for subdivisions, deci (a tenth), centi (a hundredth), and milli (a thousandth), are Latin. These prefixes are used before the name of the unit in all the tables. Reduction of weights and measures in this system simply amounts to shifting the decimal point. The Secretary of the National Union of Teachers has stated that the substitution of the metric system for our cumbrous system of weights and measures with its unrelated multiples would be equivalent to adding another year to the school life of children.

The other units are all obtained from the metre :—

A cube measuring the tenth part of a metre is the unit of capacity, and is called a litre. Ten litres make a decalitre; a tenth of a litre is a decilitre, and so on, as in the table above.

The weight of a litre of distilled water is a kilogram; of a cubic centimetre of water, a gram.

The unit of area is the are, equal to one hundred square metres.

The unit of solidity is the stere, equal to a cubic metre.

From the engineer's point of view it is undoubtedly desirable that the metric system should be adopted. Foreign customers do not understand specifications and quotations in our system, and naturally turn to other firms in metric countries. In many cases, it is true, British manufacturers use the metric system for foreign trade, and of course retain our own system for home trade. But even this involves great expense in the shops and in clerical work. In 1906, Messrs Kynoch fully adopted the metric system for every calculation relating to the interior economy of the factory. Many leading engineering firms also use it partially or entirely. In the case of Kynochs the cost of the change was stated to be one-half per cent. of a year's profits, but the saving, on the other hand, in clerical labour would repay this in the first year.

Lord Kelvin has expressed his views on the adoption of the metric system in engineering as follows:—"I believe that engineers of every branch will find the metric system exceedingly satisfactory and convenient when once they begin using it. For measures of length, large or small, the French system is vastly more convenient in every respect than our unfortunate British inches, feet, yards, rods, poles, perches (the perch, $5\frac{1}{2}$ yards), chains, furlongs, miles. In a mechanical workshop, whether for large machines or for small scientific instruments, the smallest named unit, the inch, is much less convenient than the centimetre with its named subdivision the millimetre.

"The British workman will be much happier at his work with a folding 50-centimetre rule graduated to millimetres, than with a folding 2-foot rule graduated to eighths, sixteenths, thirty-seconds of an inch. For the smallest divisions of a workman's scale, the millimetre is particularly easy to read and use, and is thoroughly convenient for the smallest named unit of length.

"I believe if a 50-centimetre folding rule was presented to each workman in a workshop of one hundred or one thousand highly skilled workmen, the employer would be more than reimbursed in a fortnight by the increase and the improved quality of the produce of his men. Any one who knows the troublesome character of handiwork described in such terms as 1″ and $\frac{3}{8}$″ and $\frac{7}{11}$″ and $\frac{17}{32}$″ will see that there will be a considerable saving of time when the workman has his job stated to him in so much more easily understood terms as $59\frac{1}{2}$ mm. Work of the highest accuracy in an engineering shop is of course ultimately controlled by accurately standardised gauges, and for these the designation, whether in inches or in centimetres, is of comparatively little importance. But it is of considerable importance to notice that the British engineer leaves thirty-seconds and jumps down to 'mils' (thousandths of an inch) in specifying gauges, or in actual work finer than the thirty-second of an inch. Not one of the accurately standardised gauges, at present in use in engineering workshops will need to be changed when the metric system is adopted.

"A very large proportion of the work in the drawing office of a civil or mechanical engineer in this country and in America is entailed by the monstrously and absurdly inconvenient and unsystematic sets of measures of length, area, bulk, and weight imposed by bondage to the present British measures."

Although many advantages would result from the introduction of the metric system, very strong objection to its compulsory use would be made on the part of manufacturing engineers, chiefly because of the expense involved in the substitution of new sets of measuring instruments of many kinds required in a modern shop. Many firms work with both systems without confusion, and it would be therefore better that the metric system should arrive by a process of evolution rather than by a drastic Act of Parliament.

The following table provides a ready means of converting kilograms into pounds and *vice versa*, or metres into yards and *vice versa*. The number in the first column may be either of the two measurements to be converted, its equivalent being found in that column belonging to the opposite system. Thus 1 yard equals ·914 metre, and 1 metre equals 1·093 yard. Intermediate quantities or fractional parts or higher multiples are easily obtained by calculation.

	Metres	Yards.		Kilograms.	Pounds.
1	0·914	1·093	1	0·454	2·20
2	1·829	2·187	2	0·907	4·41
3	2·743	3·281	3	1·361	6·61
4	3·658	4·374	4	1·814	8·82
5	4·572	5·468	5	2·268	11·02
6	5·486	6·562	6	2·722	13·23
7	6·401	7·655	7	3·175	15·43
8	7·315	8·749	8	3·629	17·64
9	8·229	9·843	9	4·082	19·84
10	9·144	10·936	10	4·536	22·05
20	18·288	21·873	20	9·072	44·09
30	27·432	32·809	30	13·608	66·14
40	36·576	43·745	40	18·144	88·18
50	45·719	54·682	50	22·679	110·23
60	54·863	65·618	60	27·215	132·28
70	64·007	76·554	70	31·752	154·32
80	73·151	87·491	80	36·288	176·37
90	82·295	98·427	90	40·823	198·42
100	91·438	109·363	100	45·359	220·46

DECIMAL EQUIVALENTS OF MILLIMÈTRES.

Mm. Inches.	Mm. Inches.	Mm. Inches.	Mm. Inches.
1 = ·03937	26 = 1·02362	51 = 2·00787	76 = 2·99212
2 = ·07874	27 = 1·06299	52 = 2·04724	77 = 3·03149
3 = ·11811	28 = 1·10236	53 = 2·08661	78 = 3·07086
4 = ·15748	29 = 1·14173	54 = 2·12598	79 = 3·11023
5 = ·19685	30 = 1·18110	55 = 2·16535	80 = 3·14960
6 = ·23622	31 = 1·22047	56 = 2·20472	81 = 3·18897
7 = ·27559	32 = 1·25984	57 = 2·24409	82 = 3·22834
8 = ·31496	33 = 1·29921	58 = 2·28346	83 = 3·26771
9 = ·35433	34 = 1·33858	59 = 2·32283	84 = 3·30708
10 = ·39370	35 = 1·37795	60 = 2·36220	85 = 3·34645
11 = ·43307	36 = 1·41732	61 = 2·40157	86 = 3·38582
12 = ·47244	37 = 1·45669	62 = 2·44094	87 = 3·42519
13 = ·51181	38 = 1·49606	63 = 2·48031	88 = 3·46456
14 = ·55118	39 = 1·53543	64 = 2·51968	89 = 3·50393
15 = ·59055	40 = 1·57480	65 = 2·55905	90 = 3·54330
16 = ·62992	41 = 1·61417	66 = 2·59842	91 = 3·58267
17 = ·66929	42 = 1·65354	67 = 2·63779	92 = 3·62204
18 = ·70866	43 = 1·69291	68 = 2·67716	93 = 3·66141
19 = ·74803	44 = 1·73228	69 = 2·71653	94 = 3·70078
20 = ·78740	45 = 1·77165	70 = 2·75590	95 = 3·74015
21 = ·82677	46 = 1·81102	71 = 2·79527	96 = 3·77952
22 = ·86614	47 = 1·85039	72 = 2·83464	97 = 3·81889
23 = ·90551	48 = 1·88976	73 = 2·87401	98 = 3·85826
24 = ·94488	49 = 1·92913	74 = 2·91338	99 = 3·89763
25 = ·98425	50 = 1·96850	75 = 2·95275	100 = 3·93700

10 mm. = 1 centimetre = 0·3937 inch.
10 cm. = 1 decimetre = 3·937 inches.
10 dm. = 1 metre = 39·37 ,,
25·4 mm. = 1 English inch.

For ·1 mm. and ·01 mm. shift the decimal point.
For numbers above 100 add the odd part.

Mica.—Mica is used in the sight holes of cupolas, and also as a packing and as a lubricant for machinery. It belongs to a group of aluminous silicates remarkable for their perfect cleavage. The laminæ are flexible, tough, and elastic, with a pearly lustre.

Talc is a very similar substance.

Micrometer—Micrometer Caliper.—The application of the micrometer principle to calipers was first made in France about 1848, and this—the Palmer system—is retained in present-day instruments. It embodies the combination of a fine pitched screw, with a thimble graduated around its periphery, passing divisions upon a hub which it encircles. Fine subdivisions of the inch are therefore obtainable by this means. In the standard types of instruments, Fig. 211 (the Brown and Sharpe), the frame A carries an anvil B and a hub C, within which runs the concealed screw, extended into a spindle D. The thimble E is fastened to the screw, and turns with it. The pitch of the screw is 40 to the inch, and the divisions along the hub are also 40 per inch, so that one complete turn of the thimble moves the spindle $\frac{1}{40}$ in. The bevelled edge of the thimble is divided into twenty-five parts, which are marked at every fifth division; if the thimble is rotated to pass from one division to another, the result is a spindle movement of $\frac{1}{25}$ of $\frac{1}{40}$, or $\frac{1}{1000}$ inch. To read the amount of opening, the number of divisions visible on the hub is multiplied by 25, and added to the number of divisions on the thimble, counting from 0 to the line which coincides with the horizontal line on the hub.

The internal mechanism of the caliper is shown in Fig. 212, from which it will be seen that the screw does not fit directly in the hub, but in a couple of nuts let into it, the one *b* at the end being finely threaded, and provided with a lock nut, so that it can be adjusted from time to time to absorb slackness between the threads, and prevent backlash. The spindle is clamped at *a* after setting, by turning the knurled nut, which is threaded to run over a tapered split bush, embracing the spindle. The fitting at *c*, shown enlarged, is a ratchet stop, a device to enable uniform pressure to be exercised on the work. It consists of a loosely revolving cap having ratchet teeth cut on the bottom, and engaging with a spring plunger in the fixed body. So long as the screw

is free to turn, the ratchet engages sufficiently to rotate it, but when the spindle end touches the work, the plunger slips down, and prevents further movement. Any number of readings can be taken uniformly, and the human element is eliminated.

Variations in detail are found in different calipers, in regard to the methods of taking up wear, and making re-adjustments so that the distance between the measuring faces shall be correct. In the instrument shown, the anvil is adjustable, to be pushed forward by a screw, and clamped by another lateral screw. In the Starrett calipers the anvil is fixed, and compensation for wear is effected by the use of a thin sleeve fitting over the hub, the graduations being placed on this sleeve, which is turned slightly when required, to bring the zero line around a little. In the Slocomb tool, Fig. 213, the longitudinal adjustment is obtained by turning the nut A in the hub, the thread being of different pitch to that of the measuring screw. Backlash is absorbed by the use of a second nut B, which engages with the face of A by vee teeth, fifty-six in number, on the faces of each. To effect take-up, the measuring screw is turned out of A, and the nut B then given a portion of a revolution, to the extent of one or two of the vee teeth, which are then re-engaged. A spiral spring between A and B maintains uniform friction between the screw and nuts. The frame of the Slocomb instrument is ribbed as shown in Fig. 213, and there are no decimal equivalents on it, as is the case with Fig. 211. Instead, the line of graduations on the hub is marked off on one side into fours, and on the other into fives, thus indicating eighths of an inch. The decimal equivalents under $\frac{1}{8}$ in. are marked on the thimble. In another class of these calipers, the frame has decimal equivalents stamped in raised letters on the flat surface, the stamping being done under hydraulic pressure of several hundred tons, which also has the effect of compressing the steel.

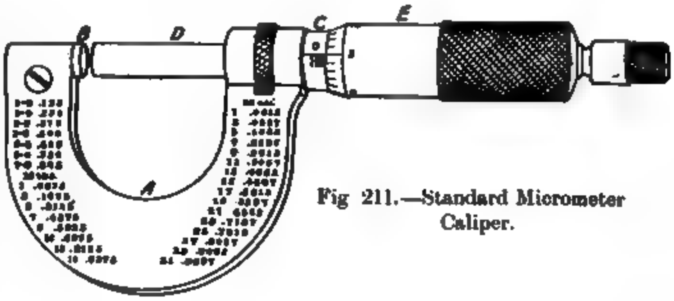


Fig 211.—Standard Micrometer Caliper.

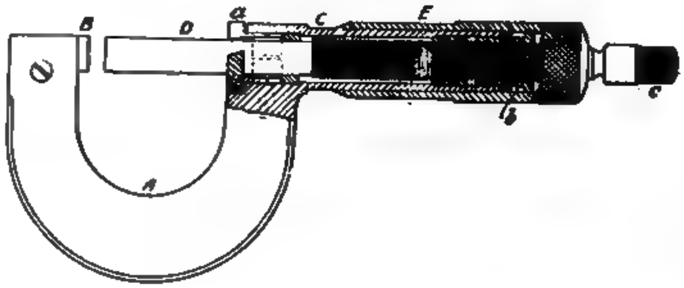


Fig. 212.—Section through Micrometer Caliper.

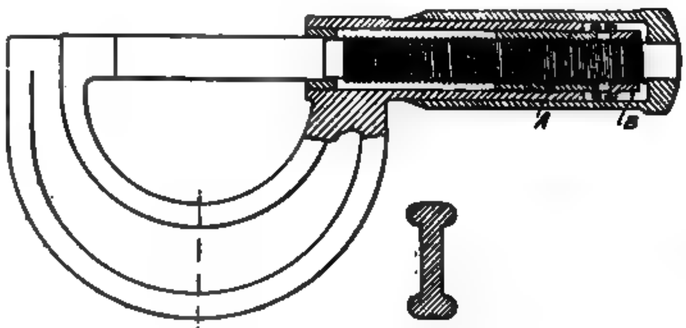


Fig. 213.—Micrometer Caliper.

The clamping ring shown in Fig. 211 differs from that in Fig. 212 in being placed centrally; the screw is dispensed with, and the spindle clamped by a split bushing, which is closed

inwards by turning the knurled outer ring, the effect of the latter being to force a small roller up an inclined plane cut on the bushing, and so squeeze it inwards.

The ordinary micrometers read to $\frac{1}{1000}$ in., although lesser amounts can be judged pretty accurately by subdividing the graduations on the thimble by the eye. But for very fine work, a circular vernier is added on the barrel. There are ten divisions, occupying the same space as nine of the thimble divisions. After

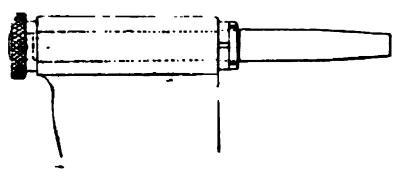


Fig. 214.—Loose Anvil.

noticing that one division on the thimble has passed the line on the barrel, thus indicating a movement of $\frac{1}{1000}$ in., the attention is directed to the coincidence of a thimble line with one of the vernier graduations. If it happens to be the second line, the thimble has moved one-tenth of the length of its own divisions $= \frac{1}{10000}$ in.; if the third line, $\frac{2}{10000}$ in., and so on. These micrometers are not used for the coarser classes of measuring, on account of the effects of wear being much more perceptible in the fine measurements taken.

When the range of micrometer calipers exceeds 1 inch, the length of movement of the measuring spindle is still limited, on account of the undesirability of giving a greater movement than an inch; two devices are then adopted according to requirements. The distance between the points is limited to sizes above 1 in. and less than 2 in., or above 2 in. and less than 3 in., and so on; or loose anvils are provided to be fitted to the frame, to give the different spans as in Fig. 214, the anvils being each secured with a nut at the end. A couple of small lock nuts placed to butt against the shoulder of the frame afford a means of giving compensation for wear. The difference in range produced by each anvil is 1 in. The usual range of these large calipers is up to 12 in., for which a horseshoe frame is preferable, with lightening holes. Metric measures are of course taken with any of the micrometer calipers, when they are graduated suitably.

Special types of micrometers are used for particular purposes. The style of frame shown in Fig. 211 is adapted as a depth gauge by flattening its left-hand side into a foot, and making the anvil with a hole right through, to admit a small rod, which passes down into the hole to be measured, and up to the measuring spindle, which indicates the depth. Screw-thread micrometers have the anvil and the spindle end shaped to embrace the sides of the thread, without actually touching at top and bottom. The anvil is recessed to a vee shape, and the spindle end forms an external vee. Some sheet-metal calipers are made with a deep gap in the frame, so that the points may be passed over some distance from the edge to get average thicknesses. Micrometers for paper, card, rubber, &c., have large discs on the anvil and spindle, to avoid the risk of

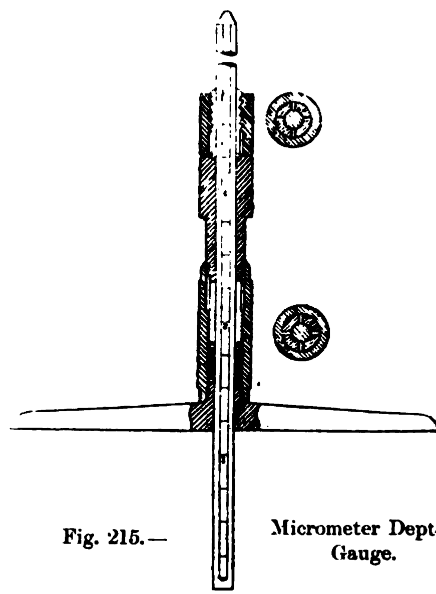


Fig. 215.—Micrometer Depth Gauge.

unduly compressing the stuff, and so registering a false size.

The German and French makers construct a good many of their micrometers with exposed screws, a practice that has been abandoned in the American tools. Readings are sometimes taken by a large divided disc on the screw, passing graduations on a flat bar beneath,

instead of utilising the barrel and thimble device already described.

The **Beam Micrometers** are treated under that heading.

Micrometer Gauge.—Applied to the internal, and the depth gauges which have micrometer devices embodied. The principle is the same as that in the **Micrometer Caliper.** In the internal gauges, the distance apart of the two end measuring points is varied by turning the thimble, and extension rods are provided to increase the range. The depth gauges, of which Fig. 215 is an example, include a foot to stand upon the work, and a rod clamped within the barrel, this rod being marked off into ½-in. divisions, as the micrometer screw

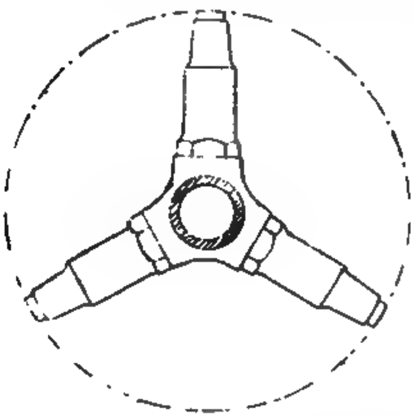


Fig. 216.—Internal Gauge.

has a movement of ½ in. only. By removing the flat foot, and screwing on a plain measuring point, the instrument is converted into an ordinary internal gauge.

The ordinary two-point gauges are liable to produce inaccurate results, if placed carelessly in their holes; to avoid this difficulty the Newall Engineering Co., Ltd., construct a three-point internal gauge, Fig. 216, which is bound to register accurately. There are three loose measuring spindles enclosed in radial arms, and the ends of these spindles are bevelled to suit the tapered end of the micrometer spindle. When the latter is moved forwards the measuring spindles are pushed outwards simultaneously, and when it is drawn backwards, coiled springs force the three spindles inwards again.

Microstructure of Metals.—Much knowledge has been gathered by the aid of the microscope respecting the minute anatomy of metals and alloys. Dr Sorby, forty years ago, was working at the preparation of sections, but the field was neglected by metallurgists until about twenty years since.

Specimens are prepared as opaque objects, and illuminated with reflected light. The chemical action produced by reagents is frequently employed to bring out certain features. The specimens are polished and mounted on slides. The fine polishing powders consist mainly of alumina, prepared from ammonia alum in various grades of division. Rough polishing is done with emery paper on rotating wooden discs. Useful magnifying powers range from 50. 140. 850 to 1 600 diameters, the

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juice. The cementing material for attaching the specimens to the glass slides is composed of resin, beeswax, red ochre, and plaster of paris. Micro-specimens reveal the effects of heat treatment, strain, the influence of minute foreign elements, and other matters in a more or less striking way, to describe which would occupy a volume. The study of the microscopic structure of metals and alloys would not be undertaken if it were a mere recreative pursuit. It has its practical bearings, illustrating what happens under the varied conditions just named. The character of crystallisation, the dimensions or orientation of crystals, the slip or cleavage planes that separate crystals, the evidence of colour, shape, hardness, and relations between alloying elements, &c., can all be studied in the photo-micrographs. The effects of annealing are visible in the growth, and in the size of crystals; the effects of strain in elongation of crystals, and in the development of *slip* lines, or incipient lines of cleavage. The study has also thrown much light on the allotropic

changes of simple bodies. The effects of heat treatment are very obvious in polished and etched specimens. The illustrations on Plate XV. are from photographs kindly supplied by Professor H. C. H. Carpenter, of the University, Manchester, whose valuable work in connection with the preparation of two of the Reports to the Alloys Research Committee, of the Institution of Mechanical Engineers is well known.

Middle Part Box.—*See* **Moulding Box.**

Mid-Feather.—The central dividing wall between the two flues in the wheel draught of a horizontal boiler.

Mid-Gear.—*See* **Link Motions.**

Mil.—A thousandth part of an inch, a unit used in connection with wire gauges. In the "New Imperial Standard Wire Gauge" the highest size, 70, is $\frac{1}{2}$ in. in diameter, the lowest, 50, is $\frac{1}{1000}$ in. or 1 mil in diameter.

Mild Centred Steel.—Steel rod having the central portion softer than the external. Has been used for screw taps.

Mill Bar. — Puddled bar as distinguished from merchant bar.

Mill Board. — Often used for making joints between pipe flanges.

Mill Gearing. — Relates specifically to the work of the millwright in the corn mills.

Milling.—The operation of a number of rotating cutters arranged equidistantly from the axis of rotation.

Milling is a rival to the single-edged cutting tools, in which lateral feed is taken after each cut. The milling cutter usually covers the entire width of the face being tooled, and its feed is then only perpendicular thereto. The single-edged tool has no time to get cool when its cut is continuous; the edges of the milling cutter, when operating axially, are off the work during a period much longer than that which is occupied in actual cutting. But this is the smallest advantage. The principal advantages are those which result from the great breadth of work covered at once, and in the facilities which the cutters afford for milling contours, especially those that are not plane.

With regard to the first-named, it is very convenient to be able to mill a surface of several inches in width without traverse feed. In this respect milling comes particularly into rivalry with the planer, shaper, and slotter. The evil which often results is that the broad cutters spring if arbors are weak and the feed heavy. It is therefore sometimes the practice to rough deeply with a milling cutter, and finish with a single-edged tool on the planer, with a fine feed.

But when profiled work has to be done, work which combines tooling at various angles and curves, milling is unapproachable. The practice of building up gang mills affords a means

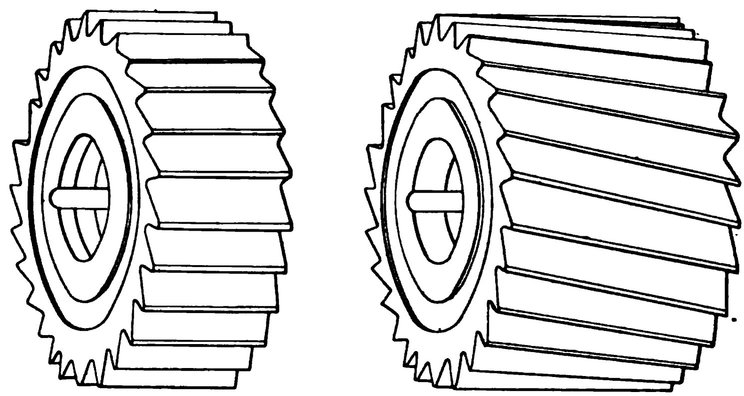


Fig. 217.—Edge Mills.

of making cutters up to a couple of feet in width, while the cutter forming and cutter grinding machines permit of making the smaller profile cutters in the solid. And when irregular shapes are required, the form cutters have no rivals. A form attachment, which includes a tool slide controlled by a weight, and a tracer pin moving against the form or templet piece, is one of the departments in which milling is most valuable. The large volume of spiral work done in the universal milling machine would not be possible without the milling cutters. Neither would the large volume of gear cutting, apart from the rotary cutters. An advantage in milling is that face and edge cutters may often be successfully substituted for each other on a piece of work. Single-edged tools used

PLATE XV.

Photo-Micrographs of Steels.

(By courtesy of Prof. H. C. H. Carpenter, of the University, Manchester.)

1. 1·30 per cent. carbon, × 120 diam. Slowly cooled. Light, cementite; dark, pearlite.
2. 0·30 per cent. carbon, cooled slowly from 900° Cent., × 120 diam. Light, ferrite; dark, pearlite.
3. 0·09 per cent. carbon, × 120 diam. *Rolled*. Light, ferrite; dark, pearlite.
4. 0·30 per cent. carbon, as *rolled*, × 120 diam. White, ferrite; dark, pearlite.
5. 1·30 per cent. carbon, as *rolled*, × 120 diam. White, cementite; dark, pearlite.
6. 1·30 per cent. carbon, slowly cooled from 900° Cent., × 500 diam. Pearlite and cementite.
7. 0·70 per cent. carbon, × 120 diam., as *rolled*. Light, ferrite; dark, cementite.
8. 1·30 per cent. carbon, quenched from 900° Cent., × 1,200. Martensite.
9. 1·30 per cent. carbon, quenched at the carbon change point, × 120 diam. Dark areas, troosite; light, hardenite.

To face page 196.

on planer, shaper, or slotter would in some situations spring, due to their overhang. A

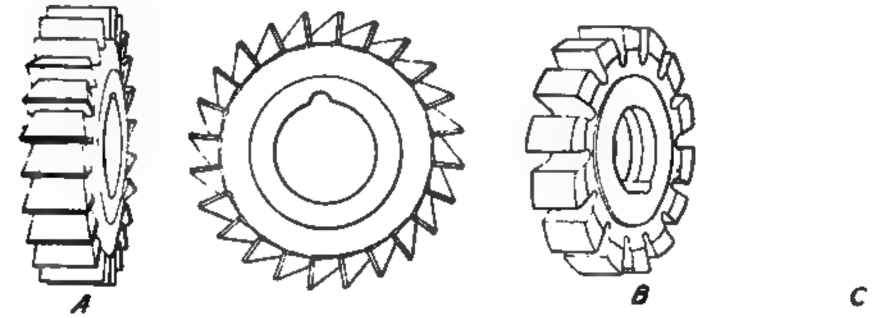


Fig. 218.—Edge Mills

face or an edge cutter could then be used without overhang and spring.

Often measurement and checking is avoided by the embodiment of measurement in the cutter, either in depthing, or width. This shows to best advantage in the gang mills and profile cutters. By the use of these also any number of similar pieces will be shaped alike without tentative checks.

Milling Cutters. — Rotating cutting tools which comprise a number of teeth or cutters arranged equidistantly from the axis of rotation, as in *edge mills;* Figs. 217, 218, or those in which the teeth are arranged round the periphery of a cylinder; or, in a plane perpendicular thereto,—*end mills,* Fig. 219, which have the teeth on the end as well as on the periphery of a rotating cylinder. Cutters vary in design in other respects besides that denoted by the terms edge, or end types. They have either straight teeth or spiral teeth, Fig. 217, and the latter are either right- or left-handed. They have continuous teeth, Fig. 219, A, B, or staggered teeth, C, or inserted teeth, Figs. 221 to 223. They comprise a

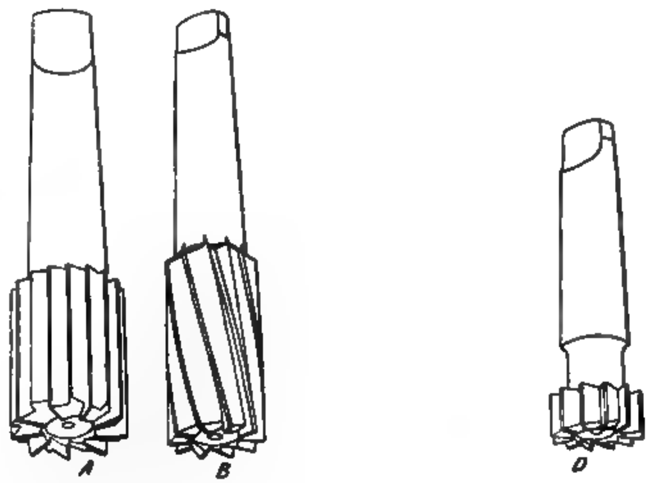


Fig. 219.—End Mills.

single element,—a *solid* mill, Figs. 217, 218, or they are built up in *gangs.* *See* **Circular Milling** They are plane, or profiled. And each type exists in a large range of proportions and dimensions. Fig. 220 shows angular

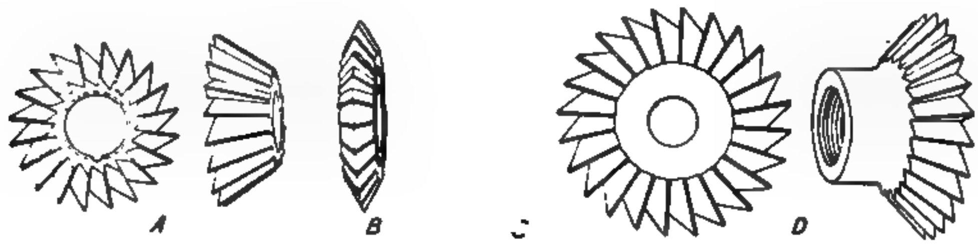


Fig. 220.—Angular Cutters.

cutters, with single angles, A, double equal, B, double unequal, C, and a bossed cutter, D, with a screwed hole.

of fastening them, as with tapered pins in splits, Fig. 221, or with screws and wedge strips, Fig. 222, or screws alone, Fig. 223, in

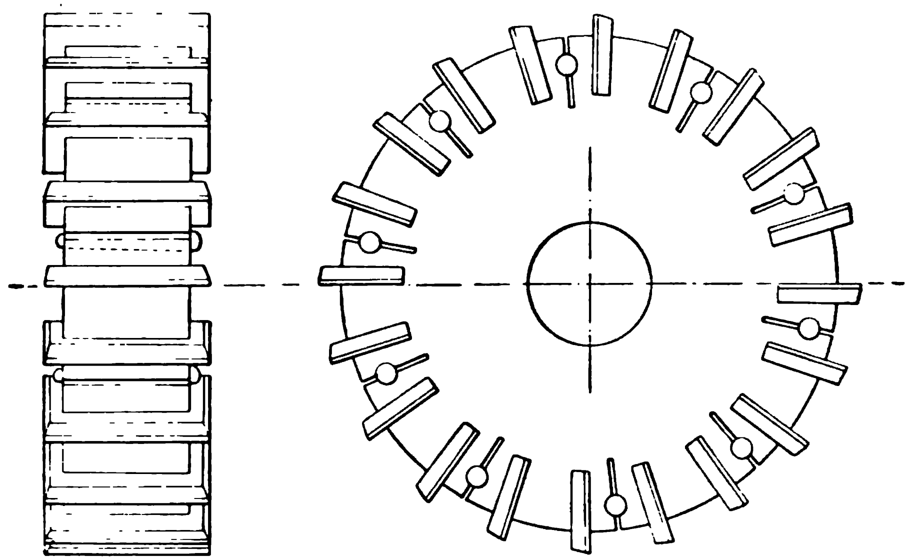


Fig. 221.—Inserted-Tooth Cutter.

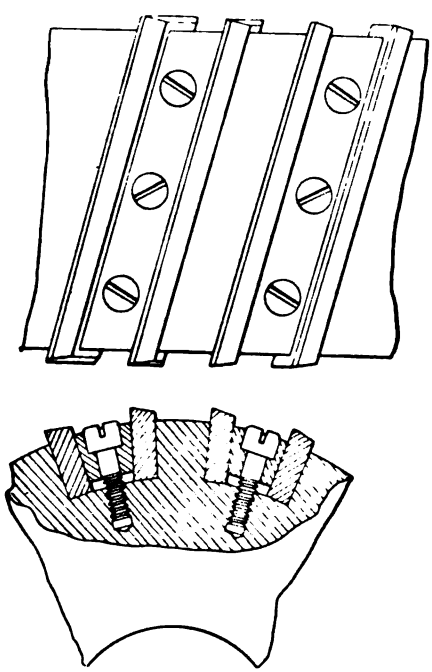


Fig. 222.—Inserted-Tooth Cutter.

Inserted-tooth cutters are used in face mills of large dimensions. There are numerous methods various ways. Many of these, Fig. 223, have a considerable amount of front rake, many differ in no wise from the roughing or finishing tools used in lathe and planer. They are essentially roughing tools, rivals to the planer and shaper. They are used in the rotary planers, or ending machines, in plano-millers, in vertical and horizontal spindle machines. Staggered cutters, Fig. 219, C, are ordinary spiral mills with spaces cut out between the teeth. Many inserted-tooth mills are also made with the cutters isolated in series. These combine the penetration of the single-edged tool with the broad cutting of the mill, and with the diagonal or spiral arrangement. They are therefore of much value in slogging.

Milling cutters lie on the border line between cutting and scraping tools. The teeth usually have no front rake, and therefore are not incisive, but scraping in action. Yet the spiral arrangement of the teeth imparted to all but the smallest mills gives a shearing action, and this with the sharpness of the edges and the effect of abundant lubrication results in the severance of true chips.

In consequence of the absence of front rake,

the teeth have little penetrative capacity, so that heavy feeding is impossible. But what is sacrificed in depth is gained in width.

The spacing of teeth varies from about $\frac{1}{4}$ in. to $\frac{3}{4}$ in. for ordinary duty, the pitch generally increasing with diameter. Mr Addy's rule is: Pitch in inches =

$$\sqrt{\text{diameter in inches}} \times 8 \times 0{\cdot}0625.$$

This takes no account of the difference in roughing and finishing. Coarsely pitched cutters absorb less power, and do more work than finely pitched ones do. They cut more freely, and the chips get away better.

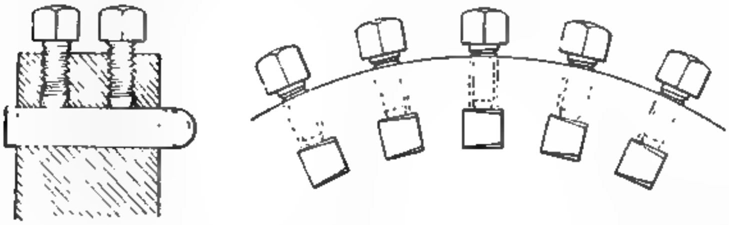


Fig. 223.—Inserted-Tooth Cutter.

The angle of clearance for cutters, *i.e.*, the angle at which the edges of the teeth are ground, varies from 3° to 8°, the latter being only suitable for brass. The angle of spiral ranges from 15° to 40°. In end mills, Fig. 219, B and C, the spirals of the sides should not exceed 20°, for if more, the end teeth become too keen.

Fig. 224.—Cutter with Tapered Shank.

Milling cutters are held on arbors by a central hole,—shell cutters, Figs. 217, 218, 220; or they are solid with a tapered shank, made to a standard taper to fit the mandrel nose, Figs. 219, 224. Fig. 224 is held to its arbor with a screw and circular nut, and keys drive it. Many tapered shanks receive shell arbors which are held with screws and nuts in various ways. *See* **Arbor**. When shell arbors are used, the key grooves are made with a radius in the corners, which lessens risk of the cutter cracking during hardening.

Milling Machines.—A large group of machines which have the one feature in common of operating milling cutters. They include machines built on the model of other machines employing single-edged tools, and ranging from very light to very massive types. Most of these, with the operations done on them, have separate treatment in these volumes.

Machines with Horizontal Spindles.—The earliest practical milling machine, which still survives, was the Lincoln model, designed by Mr Pratt, and which with several others of the same period was designed in response to the demands of the small arms factories. The characteristics of this machine are the horizontal position of the cutter arbor, carried between a fixed headstock and a tailstock, the latter generally adjustable along the bed; and the table without provision for vertical adjustment, which involves giving capacity for vertical adjustment to the spindle bearings on their housings. Feeds are imparted to the table through worm gears to the feed screw, and an automatic trip to the worm is fitted. With about one exception these machines are plain, *i.e.*, not universal in type. These machines are of greatest value for work of small and medium dimensions, and are employed largely.

A later machine with a horizontal spindle, which is an equal favourite with the Lincoln, is the pillar and knee type. In this, the headstock rigidly mounted on the standard or pillar, has no capacity for vertical adjustment. This is imparted to the knee which carries the table,

and which is fitted with slides to the front vertical face of the pillar. These machines embrace two main types, the plain, and universal. The essential difference is that the latter has a spiral head, index plate, sector, and change gears, with a swivel table. Generally there are other differences, which are not essential. Plain machines are generally built more stiffly than universal, they often have racks instead of screw feeds to the tables, and they do not contain the fine elements of precision that the others do.

A group of heavy machines with horizontal spindles are the plano-millers, or slabbing machines. The first term is derived from the build of the machine, which resembles that of the planing machine, but in which the cross-rail carries the bearings for the cutter spindle. The second term relates to the heavy or roughing character of the work done on them, with inserted-tooth, or staggered cutters. Frequently vertical spindles are fitted, and also horizontal ones on the housings, so that as many as four surfaces can be tooled simultaneously. A good many machines are also fitted with a circular work table mounted on the reciprocating table. As in planers, too, an upright is often made to be extended, or is removed wholly, making the machine open-sided.

Machines with Vertical Spindles.—These may be regarded as occupying a place analogous in some respects to the slotter. With the circular table fitting they tool circular pieces, external, and internal. Face and edge mills can be used. Generally the vertical adjustments and feeds are imparted to the spindle, the table remaining at a constant height, but there are numerous exceptions. Profiling machines are mostly built on the vertical model. The spindle drive is through toothed gears, or by belt direct. For repetition work, and for heavy duty the horizontal type of machine is to be preferred to the vertical. Gang milling can only be done on broad surfaces on a horizontal spindle; but where a number of operations on different faces have to be performed the vertical machine is often preferable.

There are also numbers of machines built or modified to perform special funetions; for cutting spur and bevel gears, worms and worm wheels; for fluting, and cam cutting, milling attachments to other machines, with two or more spindles, &c., described under separate heads in these volumes.

Millwright.—The descendant of the craftsmen who were the only engineers of a century ago. They were the development of the flour mills, which contained crude machinery and gearing driven by water wheels. The earlier engineering literature dealt mainly with this kind of work. Millwrights were alike at home when working in wood, or metal. The term is at present restricted to the men who fix shafting, belt pulleys, and gears in factories, which is really a department of fitting and erecting. It includes the cogging of mortise wheels, but not pattern-making, or moulding, or forging, in which the older hands were expert. The present-day millwright is a specialist in power transmission mechanism.

Mineral Oils.—*See* **Lubricants**.

Miner's Inch.—A term in common use in the water-power plants of the Western States of America, and in Canada. It signifies the quantity of water that will flow through 1 in. aperture (1 in. square) with a free discharge, and under a constant pressure of 6 in. above the top of the opening. An aperture $12\frac{1}{2}$ in. by $15\frac{3}{4}$ in. under a pressure of 6 in. above the top of the opening will discharge 100 inches. A miner's inch discharged in one minute is equivalent to $1\frac{1}{2}$ cubic foot $= 11 \cdot 22$ gallons. A miner's inch discharged in one hour is equivalent to 90 cubic feet $= 673 \cdot 2$ gallons.

Mining.—Includes all the processes by means of which useful minerals are obtained from the crust of the earth. These minerals embrace not only the ores of metals, but precious stones, slates, building stones, fuels (solid and liquid), clays, gravel, chalk, chemical elements, &c., &c. Useful minerals occur in igneous, stratified, and metamorphic rocks, sometimes in masses, or in veins, reefs, seams, or beds. A seam or bed is one of a group of stratified rocks, but a vein, lode, or reef is formed by the filling up of a crack or fissure with ore and vein stuff. Veins are rarely found in the later stratified rocks, but occur in earlier formations, varying in thickness from a few inches to several feet and having generally a great

inclination. Faults in seams and veins are a source of great annoyance and trouble.

Rich deposits of valuable minerals have sometimes been revealed by chance, by the uprooting of a bush, the cutting of a mill-race. Serious prospecting for minerals requires a considerable knowledge of geology, and a fair amount of chemical knowledge, for the modern prospector must be armed with a comprehensive set of reagents in readiness for chemical tests. The plough, rabbits' burrows, the character of spring water all yield information. Shallow deposits are revealed by probing with a steel rod; surface soil may be washed away or "hushed"; the magnet occasionally reveals information. Drilling or **Blasting** may be necessary to obtain sufficient mineral for testing purposes, or holes may be bored by percussive boring, and the broken matter withdrawn, or by rotary boring, by which an annular cut is made in the rock and the thin cylindrical column left standing is broken off and brought up to the surface. *See* **Bore Holes.**

As regards removal of the deposit this may occasionally be done most profitably by working it in an open quarry. In mountainous countries access to the deposit is obtained through an "adit" or "day-level," a passage or tunnel cut from the open air into the mine; the mineral is then cheaply transferred to the open by gravity. Shafts sometimes follow the inclination of the vein and are sometimes vertical. Such shafts are rectangular, and are carefully timbered. At distances varying from 60 to 100 ft. galleries or "levels" are driven out from the shaft into the vein. They are timbered, drained by a gutter, and ventilated by "winzes" or small connecting shafts, from one level to another.

The process of winning the ore is called "stoping" and this may be either underhand or overhand. In the former case the ore is worked from the floor of the level, and trammed to the shaft. As the excavation in the floor extends to a greater depth, the ore is hoisted in buckets to the floor of the level by means of a windlass, but when the level below is neared it is shot through a winze or a shoot to the lower level. In overhand stoping, the mineral is worked from above, the miners standing either on the heap of waste which continually accumulates beneath their feet, or on temporary wooden platforms.

In many respects coal mining varies considerably from metalliferous mining. In the latter case the danger of fire-damp is often absent, and naked lights are generally safe; neither does ventilation present such great difficulties. In bed or seam mining the shaft too is a much more elaborate and expensive affair, passing as it does through strata varying widely in consistency. If water-bearing strata are pierced a metal lining is necessary. The shaft is generally circular in shape. For proper ventilation two shafts are constructed, the fresh air entering the "downcast" shaft, and the bad air being extracted through the "upcast" shaft. The air in the upcast shaft is artificially heated and so made lighter than that in the downcast shaft. A current of air through the mine is thus obtained. As a rule, however, mines are ventilated by fans, the foul air being withdrawn at the top of the upcast shaft. Material is raised or lowered in cages, buckets, skips, hoppits, or kibbles by a winding engine. The mineral itself is removed by the "pillar and stall" method of working, in which pillars 50 to 60 yards square are left standing to support the roof, and which are afterwards removed; or if circumstances permit, the mineral is removed in one series of operations. This latter is called the "longwall" method and is generally adopted. The pillar and stall process is also called the "post and stall," "stoop and room" (in Scotland), and "bord and pillar" system. The use of **Coal-Cutting Machines** is also on the increase in England. For the haulage of trucks or "tubs" in the galleries the pony of earlier generations is fast giving way before the locomotive driven by compressed air or electricity.

The two gases whose presence constitutes the greatest menace to the miners' lives are **Carburetted Hydrogen**, or fire-damp, CH_4, and **Carbon Monoxide,** CO. The former is highly inflammable, and the latter extremely poisonous. **Carbon Dioxide,** or choke-damp, is produced by an explosion; it is also present in lead mines. Sulphuretted hydrogen, SH_2, is present in sulphur mines, and is also an

evil-smelling, deadly gas. *See also* **Safety Lamp.**

The minerals of chief interest in engineering are distributed geographically as follows:—

Coal.—In Great Britain—Northumberland, Durham, Yorkshire, Lancashire, Derby, Staffordshire, Monmouthshire, Nottinghamshire, Glamorgan, Denbigh, Carmarthen, Lanarkshire, and Kilkenny; U.S.A.; Germany; France; Belgium; Russia; Austria-Hungary; Japan; and India, Canada, New South Wales.

Iron.—In Great Britain—the Cleveland district of Yorkshire, Leicester, Lincoln, Northampton, Ayr, Lanark, Renfrew; U.S.A.; Germany; Sweden; Russia; Austria-Hungary; Belgium; Spain.

Copper.—Cornwall and Devon; U.S.A.;

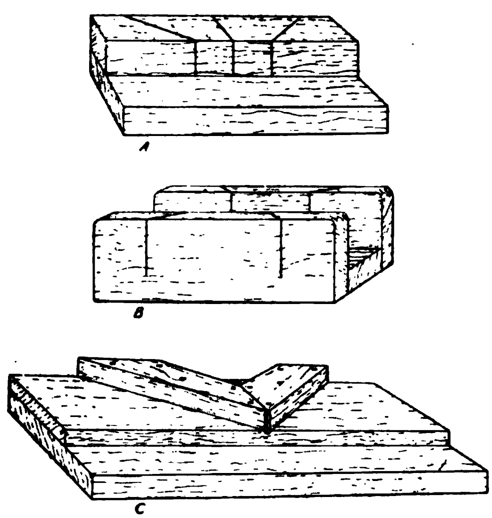


Fig. 225.—Mitre Block, Box, and Shoot.

Spain; Mexico; Japan; Chile; Australia and Canada.

Tin.—Cornwall; Malay States; Bolivia; Dutch East Indies; Australia.

Lead.—Flint, Durham, Derby; U.S.A.; Spain; Germany; Mexico; Australia.

Nickel.—None in Britain; Canada; U.S.A.; New Caledonia.

Zinc.—Wales, Cumberland, Isle of Man; Germany; U.S.A.; Italy; Spain; Sweden; Algeria; Australia.

Mitre, or Mitre Joint.—The commonest example of this is a plain joint at the angle of 45° between two pieces meeting at right angles. The term also includes radial joints between pieces meeting at other angles than 90°, but it is then generally qualified as an obtuse or acute mitre.

Mitre Block.—A block of wood with saw cuts in it at the angle of 45°, Fig. 225, A. It is used on the bench as a guide for the tenon saw in cutting similar angles on pieces of wood held against it on the lower board.

Mitre Box, Fig. 225, B.—This serves the same purpose as a mitre block, the only difference between them being that the box has sides with cuts for guiding the saw, and the wood to be sawn is held inside the box instead of against the outside of the block.

Mitre Machine.—A machine of the trimmer type worked by a lever, and provided with knives and guides for cutting the ends of pieces of wood to the angle of 45°. Small mitre machines for picture-frame work are fixed to the angle of 45°. Others are adjustable, so that they can be used for other purposes, and are then called trimmers.

Mitre Shoot, or Mitre Board, Fig. 225, C.—A board on which pieces of wood are laid to have one end planed at the angle of 45° to the surface that bears against the stop on the board.

Mitre Wheel.—A bevel wheel, the pitch cone of which makes an angle of 45° with the axis of revolution.

Mixed Flow.—*See* **Turbines.**

Module.—The module, or modul, is the equivalent of diametrical pitch, but expressed in millimetres, and is therefore the metric unit. It is the pitch diameter in millimetres, divided by the number of teeth in a wheel. The following formulæ are therefore deducible from it:—

$$\frac{\text{Pitch diameter}}{\text{Number of teeth}} = \text{module.}$$

$$\frac{\text{Whole diameter}}{\text{Number of teeth} + 2} = \text{module.}$$

$$\text{Number of teeth} + \text{module} = \text{pitch diameter.}$$

$$(\text{Number of teeth} + 2) + \text{module} = \text{whole diameter of wheel.}$$

$$\frac{\text{Pitch diameter}}{\text{Module}} = \text{number of teeth.}$$

$$\frac{\text{Whole diameter}}{\text{Module}} - 2 = \text{number of teeth.}$$

$2 \times$ module $=$ working depth of teeth.

Module $\times$ 1·5708 $=$ thickness of teeth on pitch line.

Module $\times \frac{1 \cdot 5708}{10} =$ amount added to depth for clearance.

For teeth on this principle a separate special set of cutters is made. They number eight for each pitch, just as in the English diameter pitch.

Modulus.—A function, a ratio convenient for calculations; thus there are moduli for strength, elasticity, &c. The modulus of direct elasticity is the ratio $E = \frac{p}{l}$, where p is the stress per unit section of a bar, and l the extension or compression per unit of length. The modulus of transverse elasticity is $G = \frac{q}{n}$, where q is the shearing stress per unit of area, and n the distortion. The distortion is measured by the tangent of the difference of the angles of a specimen before and after the application of stress.

The modulus of a section, also termed the "strength modulus," or "modulus of strength," is obtained from the moment of inertia of a section. If this, "I" is divided by the number of inches x at which the extreme edge of a beam is situated from the neutral axis, the strength modulus Z is obtained. $Z = \frac{I}{x}$. The greatest stress at the extreme edge $= \frac{\text{bending moment}}{Z}$. And the bending moment at any section divided by Z must not exceed the breaking strength of the material. Conversely, the moment of resistance of a material of a given section must be equal and opposite to the bending moment.

Molecule.—Is the smallest portion of a body (simple or compound) which can occur in the free state; it consists of a group of atoms or even of one atom, as in argon, and may be divided by chemical processes though not by any mechanical means. The molecules of an element are composed of atoms of the same kind, but the molecules of a compound are composed of dissimilar atoms. As regards their dimensions, Lord Kelvin has said that if a drop of water were magnified to the size of the globe, the molecules would merely vary in size between a small shot and a cricket ball!

The presence or absence of certain physical properties of the metals is due to the greater or less cohesion among the molecules. Welding is, in chemical language, the interpenetration of molecules raised to a high temperature.

Molybdenum (Mo. 96).—This is a brittle metal with a silver-white lustre, obtained from the ore MoS_2, molybdenum disulphide, a mineral not unlike graphite in appearance. It is chiefly of interest owing to its connection with high-speed tool steels produced by the introduction of alloys of chromium-molybdenum, or chromium-tungsten. Molybdenum readily unites with iron, acting very similarly to tungsten. Nearly 10 per cent. of molybdenum (or tungsten) is present in high-speed tool steels. *See* **High-Speed Tool Steels.**

Moment of Inertia.—If each particle of the mass of any solid body be multiplied by the square of its distance from a given axis, the algebraic sum of the products so obtained is termed the moment of inertia of the body with respect to that axis. *See* **Inertia.**

Similarly the moment of inertia of an area or a section may be obtained by multiplying each elementary area by the square of its distance from a common axis, and taking the sum of the product. The moment of inertia may vary in the same section according to the selected position of the axis; thus in considering the section of a rolled steel joist or **H** beam two definite values of I are usually calculated: one is termed the greatest moment of inertia, and has its axis at right angles to the web of the joist, the other is termed the least moment of inertia, and has its axis central and parallel with the web. The moment of inertia of a simple section may be calculated in one operation, viz.:—

$$\text{Solid circle } I = \frac{\pi D^4}{64}$$

$$\text{Hollow circle } I = \frac{\pi(D^4 - d^4)}{64}$$

$$\text{Solid square } I = \frac{B^4}{12}$$

$$\text{Solid rectangle } I = \frac{BH^3}{12}$$

Where $D =$ outside diameter, $d =$ inside diameter, $B =$ breadth, and $H =$ depth.

Two important values may be deduced from the moment of inertia of a section: the modulus of the section, and the radius of gyration. The first named, when multiplied by "stress per square inch," gives the "moment of resistance" or strength of the section to resist bending forces. The modulus is obtained by dividing the moment of inertia by the distance of the farthest fibres from the axis; for it is on these fibres that the greatest stress occurs. The letter Z is usually employed to denote modulus of section; for simple sections it may be calculated without reference to I, as follows:—

$$\text{Solid circle } Z = \frac{\pi D^3}{32}$$

$$\text{Hollow circle } Z = \frac{\pi(D^4 - d^4)}{32\ D}$$

$$\text{Solid square } Z = \frac{B^3}{6}$$

$$\text{Solid rectangle } Z = \frac{BH^2}{6}$$

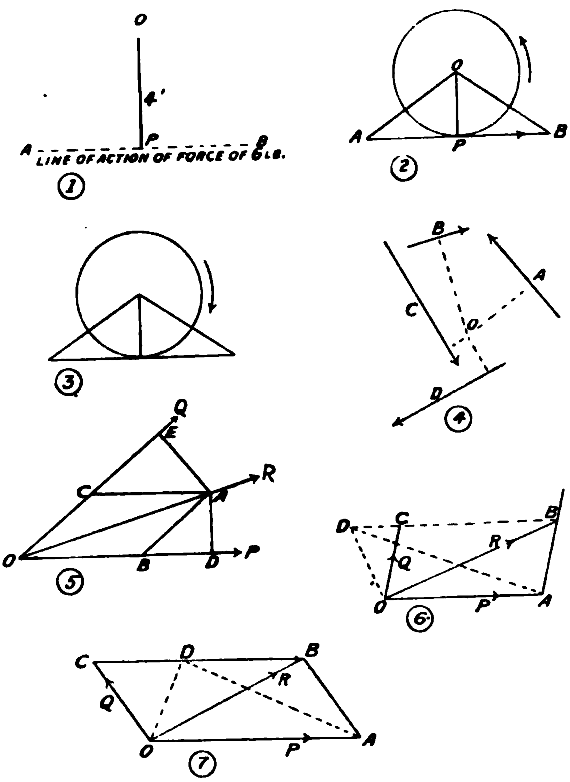


Fig. 226.—Moments.

The radius of gyration is the distance from the axis of the section to the centre of gyration. *See* **Gyration, Centre of.** It is used largely in estimating the strength of columns. *See* **Columns,** for method of calculation, and also application.

Moment of Resistance.—Equivalent to the strength of a beam or structure to resist bending or rupture.

Moments.—The moment of a force about a fixed point is the tendency of that force to produce rotation. A common concrete example is seen in the shutting of a door. The fixed axis is represented by the hinges, and the force is applied at some distance from the axis, and at right angles to the plane of the door. It is clear, too, that the effect of the force varies with (1) the magnitude of the applied force; (2) the distance from the axis at which the force is applied.

The moment of a force is therefore the product of the magnitude of the force, and the perpendicular distance from the axis or fixed point to the line of action of the force. In Fig. 226 (1 and 2), where a force of 6 lb. acts at a perpendicular distance of 4 feet from the point O, the moment of the force about that point is $OP \times AB = 24$ foot pounds. A force cannot, of course, have any moment about a point when the line of action of the force passes through that point. For in that case $OP = O$ and therefore $AB \times O = O$.

The product of the line AB, Fig. 226 (2), representing the force, and the perpendicular OP, is, however, twice the area of the triangle AOB, and hence the moment of a force about a point may be stated as twice the area of a triangle whose apex is the fixed point, and whose base is the line representing the force.

Moments are distinguished as positive and negative. When, as in Fig. 226 (2), the tendency is to produce rotation in the opposite direction to that of the hands of a clock the moment is spoken of as positive, and denoted by the sign +; if on the contrary the moment tends to produce rotation in the same direction as that of the hands of the clock (3),

the moment is negative and denoted by the sign $-$.

To discover whether a body will be kept in equilibrium by a series of forces it is necessary to find the algebraical sum of the moments. Let it be required to find the sum of the moments of A, B, C, D round O, where A = 5 lb., B = 3 lb., C = 7 lb., and D = 6 lb., and the perpendicular distances or arms are for A 4′, B 5′, C 1′, D 2′.

	Force.	Arm.	Clockwise Moment.	Anti-clockwise Moment.
A.	5 lb.	4 ft.	...	20 ft. lb.
B.	3 lb.	5 ft.	15 ft. lb.	...
C.	7 lb.	1 ft.	...	7 ft. lb.
D.	6 lb.	2 ft.	12 ft. lb.	...
...	...	...	27 ft. lb.	27 ft. lb.

Positive and negative moments being equal the body would be in equilibrium.

An important proposition in moments is that if any point be taken in the line of action of the resultant of two forces the moments of the forces about that point are equal—their algebraical sum is zero. In Fig. 226 (5), P and Q are forces acting at O, and R is their resultant. Take any point A in the line of action of the resultant. Draw AB, AC parallel to QO, PO respectively. Then—

OA represents R
OB „ P
OC „ Q.

Then, as stated above, the moment of P round A is represented by twice the area of the triangle OAB, and similarly the moment of Q by twice the area of the triangle OAC. But as these triangles are equal (for the opposite sides and angles of parallelograms are equal to one another, and the diameter bisects them—Euclid, I. 34), the moments of P and Q about A are also equal; that is $P \times AD = Q \times AE$. From this proposition a useful deduction may be made, namely, a body under the action of two forces will be in equilibrium when the point of support is in the line of action of the resultant.

Another important truth known as Varignon's Theorem is that the sum of the moments of two forces about any point is equal to the moment of their resultant about that point. Let D be the point, Fig. 226 (6), P and Q the forces, and R their resultant. From D draw a line parallel to OA, cutting the line of force Q at C. OC now represents Q, and OA must be of such length that it represents P on the same scale, *i.e.*, OA : OC : : P : Q. Complete the parallelogram. OB then represents the resultant R of P and Q. In this figure the moments of P, Q, R are all positive or anti-clockwise, and are severally represented by twice the areas of the triangles DOA, DOC, DOB. The truth of the theorem will then be shown if it can be proved that twice the sum of the triangles DOA and DOC equals twice DOB, or in the form of an equation: $2DOA + 2DOC = 2DOB$. Now the triangle DOA equals triangle BCO (for triangles on equal bases and between the same parallels are equal to one another—Euclid, I. 38). Therefore, $2DOA + 2DOC = 2BCO + 2DOC = 2DOB$. Therefore the sum of the moments of P and Q equals moment of R.

Let the point D be so situated that the moment of P is positive and that of Q negative, Fig. 226 (7). It is now necessary to prove that $2OAD - 2ODC = 2OBD$. The triangle OAD equals triangle OBC. Therefore $2OAD - 2ODC = 2OBC - 2ODC = 2OBD$. Which was to be proved.

The term moment, considered above from the abstract point of view, is used in many special connections, but the underlying idea is always moment = arm × force. A **Beam** yields when the breaking moment or moment of rupture is greater than the moment of resistance; the question of retaining and other walls for supporting lateral pressure is largely concerned with the ratio of the overturning moment of the applied force and the moment of stability of the wall; shafts are subjected to a twisting moment or torque; and the moment of inertia of a body is represented by the formula $I = \Sigma \times d^2 \times w$, in which the Greek letter sigma designates the sum of the particles composing the body, d the distance from a given point or axis of rotation, and w the weight (or mass) of each particle.

Momentum.—Is the product of the mass of a body and its velocity. The relation between

velocity and momentum has been happily likened to that between temperature and heat; the temperature of the air in two rooms of unequal size may be the same, but there is a greater quantity of heat in the larger room. Similarly two bodies of unequal mass may have the same velocity, but that containing the greater quantity of matter will possess a greater quantity of motion than the other. The momentum of a body may thus be increased while its velocity is unaltered, or even decreased.

The unit of momentum is the momentum of a unit mass moving with a unit velocity. In the foot-pound-second system (F.P.S.), the unit is the momentum of 1 lb. moving at the rate of 1 ft. per second. In the centimetre-gram-second system (C.G.S.), the unit is the momentum of 1 gram moving at the rate of 1 centimetre per second.

Mond Gas.—This is the name given to a fuel or power gas, the invention of Dr Ludwig Mond, the eminent chemist. The process was first in successful operation at the works of Brunner, Mond, & Co., at Winnington in Cheshire, whose gas plant has a capacity of 250 tons of coal a day, which are turned into gas at the rate of over a million cubic feet per hour. It produces a much cheaper gas than that made by any other method. It is suitable for heating furnaces, for driving the largest gas engines, and for supplying a cheap source of power over a large radius. It is also better than blast furnace gas because of its higher calorific value, and its freedom from dust. The average cost of producing a unit of electricity at the switchboard, with ordinary central station dynamo plant, at a good load factor, is ½d. At Winnington, using the Mond gas, the fuel cost is less than one-twentieth of a penny, and the total cost is less than one-tenth of a penny. This economy is effected thus:—

In the first place the commonest bituminous slack, at ordinary times obtainable for 3s. or 3s. 6d. a ton at the pit's mouth, is used, being worth 6s. to 7s. a ton when delivered. Here the Mond product is at an enormous advantage, compared not only with illuminating gas, but with other producer gases. The cheap slack costs but half the price of ordinary coal in many localities, less than half as much as the coke, or one-third that of the anthracite coal that must be used in other methods in order to avoid caking of the fuel.

In the Mond process, also, a large quantity of valuable ammonia may be obtained. About 70 per cent. of the nitrogen present in the coal can be recovered as sulphate of ammonia, by washing the gases, while in other processes it is partly or wholly lost. Ammonia is recovered in the making of illuminating gas, but not to nearly so great an extent, about 20 lb. as sulphate of ammonia being recovered per ton of coal burnt, against four to five times that quantity in the Mond process. Sulphate of ammonia is worth about £11 a ton at the works, equivalent to a saving of about 5s. on each ton of slack gasified, or nearly as much as the average cost of the small coal used. To recover the ammonia, the temperature of the producer or furnace has to be kept low, otherwise it would be reconverted into nitrogen and hydrogen. Hence a large volume of steam is turned in, equal in weight to 2 to 2½ tons per ton of fuel gasified in the producer. This is not lost, since a portion is decomposed, rendering up hydrogen, which is so valuable a heating agent. Further economies are effected in the heat and steam recovery apparatus, by which the heat of the gas itself and its burden of steam is largely recovered, and rendered up to the air blast instead of being wasted, and this also is a large factor in the economy. Mond gas is therefore cheaper than any other power gas. It is not as poisonous as water gas, since it only contains 11 per cent. of carbon monoxide, which is 3 per cent. within the Board of Trade limit. It is so clean that engines driven by it have run for six months without stopping.

The Mond gas producer (*see* Fig. 227) consists of two cylindrical shells, one within the other. The inner is the combustion chamber, the outer an air jacket. The producer is surmounted by a hopper, and a special distributor which distributes the fuel evenly over the whole of the fuel bed, which enhances the rate of gasification, the constancy of the gas, and still further increases the ammonia yield. The outer shell is continued down to a water lute in the base, into which the ashes descend, and from which the latter are removed at regular intervals. By this means the operation of removal of ashes is carried out without any interruption

of the working of the producer. The fuel in its descent is subjected to an air blast which is saturated with steam at 185° Fahr. and super-heated to from 400° to 500° Fahr. Tl of steam introduced with the blast a stated, to 2 to 2½ tons per ton of fuel g this about ½ ton is decomposed in th yielding a large quantity of free hyd the undecomposed steam about 1 ton fuel gasified is recovered, and used ov again. The presence of steam keeps down the working temperature of the producer, and prevents the formation of clinkers, or the destruction of the ammonia.

As the hot gas and decomposed steam leave the producer, they pass through a tubular regenerator in the opposite direction to that taken by the entering blast. The blast is thus superheated, and it receives more heat by passing down the annular space which separates the inner and outer shells of the producer on its way to the fire-grate. The products from the producer now pass through a washer,—a rectangular chamber of sheet wrought iron, with side lutes. Here they meet a water spray thrown up by revolving blades. The effect is steam and gas down to about 180° to almost saturate the gas with water this temperature, thus converting tl the sensible heat of the gas into the la at the same time effectually removin or dust which passes from the produc gas. At this stage the ammonia is by passing the gas through a lead-li fitted with tiles, and exposed to a flow of acid liquor containing sı ammonia, with about 2 per cent. exc sulphuric acid. Combination of the a the gas takes place with the free aci more sulphate of ammonia Sulphat being constantly withdrawn from circı evaporated to yield solid sulphate of and some free acid is being constantl the liquor in circulation, thus cons perfectly continuous process.

The gas, freed from ammonia, is now passed through a tower where it is cooled and cleaned by a downward flow of cold water. The cooling water becomes

Fig. 227.—Diagram of Mond Gas Plant with Recovery of Ammonia. (The Power Gas Corporation, Ltd.)

through this tower the air is heated, and saturated with steam to a temperature of 160° Fahr.,

and the water being thus cooled is pumped again up to the top of the gas cooling tower. Both towers are fitted with tiles to give large surfaces of contact. By utilising the heat of the gas from the producer, nearly 1 ton of steam is added to the producer blast for every ton of fuel gasified. In a Mond gas plant the amount of gas generated is from 120,000 to 150,000 cubic feet per ton of coal, depending upon the quality of coal in use. The calorific value averages 150 B.T.U. per cubic foot, and the gas has not only been found suitable for use in gas engines of all sizes, but also for furnace operations, steel being melted with it in open-hearth furnaces most satisfactorily. There are at present in operation, Mond gas plants capable of producing over 360,000,000 cubic feet of gas per diem. Mond gas plants of small sizes are also built without the ammonia recovery apparatus.

Monkey.—*See* **Pile Driver.**

Monkey Wrench.—An adjustable wrench, named after Mr Monckey.

Monolithic Work, Mass Concrete, or **Concrete in Mass.**—Designates a solid construction in concrete, as distinguished from that built of blocks cemented together, or in bags.

Monolithic work was carried out by Mr Cay on a large scale and in a novel way at Aberdeen, where blocks were cast *in situ* from 335 to 1,300 tons weight. The piece of the breakwater to be operated on was surrounded with timber posts with grooved sides, panels were dropped into these grooves as the filling proceeded, the floor and sides were lined with jute cloth, and the whole tied together with ¾-in. iron tie rods. In this way, by beginning before low water, and hastening the work by putting in large stones and concrete blocks, the surface of the soft concrete was always kept above the tide level outside, and the concrete set solidly and became of great strength.

Another example of plastic work is at Wicklow Harbour, where a breakwater 750 ft. in length, and 30 ft. wide at the top, is built of solid concrete. The concrete was deposited from skips on a bottom, part of which was composed of rock, part of marl. Temporary staging carried the cranes, the uprights being secured in concrete shoes. Timber panelling in sections enclosed and confined the concrete during deposition. Sometimes as much as 250 cubic yards of concrete were deposited in a day.

To avoid the cracks which occur in long masses of concrete laid in a plastic condition, and which are due to variations in temperature, the Wicklow breakwater has vertical divisions running transversely at intervals of about 40 feet, starting from the level of low water upwards. Higher up, intermediate separations are made, and higher still, others, so making an articulated structure of the breakwater, affording freedom for expansion without risk of cracking.

At Wicklow Harbour there is a lighthouse, the cupola of which is formed of plastic concrete swept up with a strickle on temporary brick-work, just as moulders sweep up moulds in loam.

One of Mr Kinipple's works was a concrete wall along the face of the steamboat quay at the entrance to the West Harbour, Greenock. This wall is 1,150 ft. long, and from 3 ft. to 17 ft. in thickness. It was formed between two rows of sheet piling, in depths of from 15 ft. to 30 ft. below high water and 6 ft. above high water.

In another case, that of the Girvan Harbour extension works in Ayrshire, a pier was built of plastic concrete in short lengths of 15 ft. Instead of sheet piling, a facing of moulded concrete blocks with dovetails on their backs to bond them into the concrete hearting was deposited. Dovetailed grooves on the faces were filled with quick-setting cement, making a water-tight dam, behind which the plastic concrete was laid. In addition to this, their stability was further ensured by pouring grouting through vertical holes, both in the blocks and in their joints, which helped to cement them together. The composition of the blocks was 1 of Portland cement to 4 parts of sand and fine gravel, and the faces were rendered with a coat of 1 to 1 Portland cement mortar, ½ inch thick.

Another way in which plastic concrete may be used is in sailcloth in situations too exposed to permit of laying of facing walls. Sand bags are piled up and lined with sailcloth, into which the plastic concrete is deposited. When

full, the cloth is folded over and weighted until the concrete has set. When the block has hardened, the sand bags are removed, and the sailcloth cut away. Adjacent blocks are formed against those first laid, so that the pile of bags is only required on the sides away from the finished blocks. The casing may be of timber instead of sand bags. An example of this kind occurred at Colombo, where an abutment block of concrete weighing 320 tons was deposited on jagged rock in this way, in 16 ft. to 24 ft. of water

At Fraserburgh Harbour, Scotland, the breakwater is formed of concrete in bags, and monolithic work laid in plastic concrete. The concrete in bags weighed from 28 to 50 tons to just above low water. They were deposited from the well of a hopper barge. The breakwater contains 15,274 cubic yards in bags, and 25,106 cubic yards of monolithic work. The proportions used in the bags were 1 of Portland cement to 7 of sand and stones at the shore end, and 1 to 4½ as the breakwater lengthened out into the ocean currents. The plastic concrete was composed of 1 to 9 in the summer, and 1 to 7 in the stormy season, a larger proportion of cement being found necessary for strength.

Morphidites.—A synonym for hermaphrodite calipers.

Morse Tapers.—A system of standard tapers which are in general use for the shanks of drills, and similar tools, milling cutters and arbors, lathe centres, and other fittings that are driven in this manner. The tapers are numbered from 0 to 7, particulars being given in the following table, which is read in con-

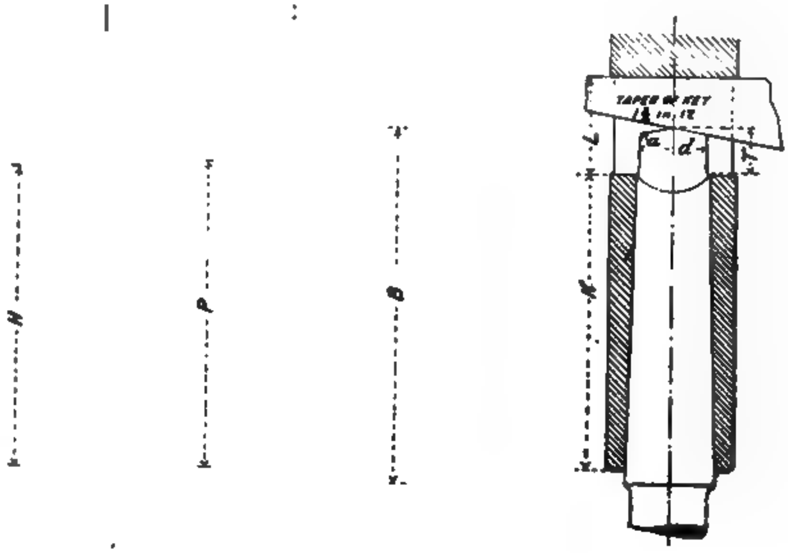


Fig. 228.—Diagram of Morse Tapers and Shanks (see Table).

Number of Taper.	Diameter of Plug at Small End.	Diameter at End of Socket.	Standard Plug Depth.	Whole Length of Shank.	Depth of Hole.	End of Socket to Key Way.	Length of Key Way.	Width of Key Way.	Length of Tongue.	Diameter of Tongue.	Thickness of Tongue.	Radius of Mill for Tongue.	Radius of Tongue.	Shank Depth.	Taper per Foot.
	D	A	P	B	H	K	L	W	T	d	t	R	a	S	
0	·252	·356	2	$2\frac{11}{32}$	$2\frac{1}{32}$	$1\frac{15}{16}$	$\frac{9}{16}$	·160	$\frac{1}{4}$	·24	$\frac{5}{32}$	$\frac{5}{32}$	·04	$2\frac{7}{32}$	·625
1	·369	·475	$2\frac{1}{8}$	$2\frac{9}{16}$	$2\frac{3}{16}$	$2\frac{1}{16}$	$\frac{3}{4}$	·213	$\frac{5}{16}$	·35	$\frac{13}{64}$	$\frac{3}{16}$	·05	$2\frac{3}{8}$	·600
2	·572	·700	$2\frac{9}{16}$	$3\frac{1}{16}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$\frac{7}{8}$	·26	$\frac{3}{8}$	$\frac{17}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	·06	$2\frac{7}{8}$	·602
3	·778	·938	$3\frac{3}{16}$	$3\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{16}$	$1\frac{1}{16}$	·322	$\frac{7}{16}$	$\frac{3}{4}$	$\frac{5}{16}$	$\frac{9}{32}$	·08	$3\frac{9}{16}$	·602
4	1·020	1·231	$4\frac{1}{16}$	$4\frac{3}{4}$	$4\frac{1}{8}$	$3\frac{7}{8}$	$1\frac{1}{4}$	·478	$\frac{5}{8}$	$\frac{31}{32}$	$\frac{15}{32}$	$\frac{5}{16}$	·10	$4\frac{3}{4}$	·623
5	1·475	1·748	$5\frac{3}{16}$	6	$5\frac{1}{4}$	$4\frac{15}{16}$	$1\frac{1}{2}$	·635	$\frac{3}{4}$	$1\frac{13}{32}$	$\frac{5}{8}$	$\frac{3}{8}$	·12	$5\frac{3}{4}$	·630
6	2·116	2·494	$7\frac{1}{4}$	$8\frac{5}{16}$	$7\frac{3}{8}$	7	$1\frac{3}{4}$	·76	$\frac{7}{8}$	2	$\frac{3}{4}$	$\frac{1}{2}$	·15	8	·626
7	2·75	3·27	10	$11\frac{5}{8}$	$10\frac{1}{8}$	$9\frac{1}{2}$	$2\frac{5}{8}$	1·135	$1\frac{3}{8}$	$2\frac{11}{16}$	$1\frac{1}{8}$	$\frac{3}{4}$	·18	$11\frac{1}{4}$	·625

junction with the drawing, Fig. 228, of a spindle, and shank for various kinds of tools.

Mortar.—The cementing substance used in building masonry in air. Mortar comprises two portions, the *aggregate*, and the *matrix*. The first is the body, the second the cementing material. The aggregate is composed of sharp sand, or crushed brick, or sandstone, or ashes; screened, and free from salt, loam, or clay. The matrix is lime, blue lias lime being the best, and Portland cement in various proportions: 1 part of hydraulic lime may be mixed with 3 to 4 parts of aggregate; or 1 part of Portland cement to 2 or 3 parts of aggregate. No more should be mixed than can be used on the same day, and the more quick-setting the cement used, the shorter should be the interval between mixing and use.

Mortar Mill.—A circular pan revolved by gearing under heavy rollers, or *vice versa*, by which the materials are crushed and amalgamated. Plates direct them under the rollers. The diameters of pans at the top range from 4 ft. to 9 ft. Such mills are commonly belt driven from a portable or semi-portable engine.

Mortice and Tenon.—*See* **Joinery**.

Mortice Chisel.—*See* **Chisel**.

Mortice Wheel Patterns.—These are either full patterns, or sectional parts for moulding by machine. The differences in these and ordinary wheels are those due to the thicknesses of their rims, and to the substitution of core prints for teeth. It is not necessary, therefore, to describe the details of building up the rims and arms, as these differ in no respect from the corresponding rims of bevel gears and spur gears, described under these headings. The prints make the only difference.

Spur Gear Patterns.—In spur mortice gears the prints, Fig. 229, A, may be about an inch thick in patterns of average size, even though the rims may be from 2 in. to 3 in. thick; for the cores bed against the mould that corresponds with the interior of the rim, Fig. 229, C, so that a print thickness sufficient for counterbalance is unnecessary. The prints reach to the top edge of the pattern rim, for if they terminated with the top of the mortice a down-joint would have to be made by the moulder. The cores are made to stop themselves off at the proper height. The prints are tapered at the sides, not necessarily on the faces. This taper, and the provision for stopping off are effected in the core box, Fig. 229, B. A comparison with prints and box will render their relations clear. The rim is pitched round for the number of teeth required, and the prints, having a gauged centre line, are nailed or screwed to the pitch centres. The absolute accuracy necessary in the teeth is not essential in the prints.

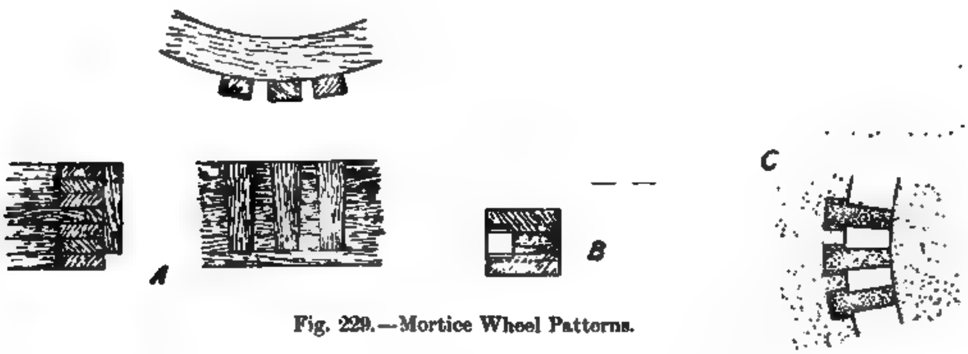


Fig. 229.—Mortice Wheel Patterns.

Bevel Gear Patterns.—In these, the prints, Fig. 230, A, are thinner than in spurs, seldom exceeding from $\frac{3}{8}$ in. to $\frac{1}{2}$ in., the reason being that the cores, lying at a bevel, are well supported in a shallow impression. To permit the prints to deliver, the tops are bevelled to lie perpendicularly, A. The prints have the same taper as the mortices, but they are tapered at

the edges. This, and the stopping up of the bevel at the top is formed in the core box; compare B with C.

Mortice Wheels, or **Cog Wheels.**—Wheels having teeth of wood to engage with iron teeth. Both spur and bevel wheels are made thus for mill work, in cases where the noise arising from gears wholly of metal would be objectionable. The reason lies in the yielding character of the wood, which absorbs shocks, and is not resonant. Though the absolute strength in iron-toothed wheels to resist a dead load is more than twice as great as that of wooden teeth as usually proportioned, yet the wooden teeth have slightly more power of transmission.

The proportions given to mortice wheels have been settled by practice within narrow limits. If p = pitch, the thickness of the tooth is $0{\cdot}6p$, Fig. 231, leaving the space $0{\cdot}4p$, and the latter is the thickness of the iron tooth. This difference is essential because of the difference in the strength of timber and iron. No flank clearance is allowed. For the same reason the length of tooth is less than that of iron and iron teeth of similar pitch; the height is $0{\cdot}55p$, being $0{\cdot}25p$ above pitch line, and $0{\cdot}3p$ below. In bevel wheels these proportions are taken on the major diameter. The rim of a wheel is weakened so much by the mortices, and has to resist the stresses of driving the teeth, that its thickness is usually made equal to the pitch, or sometimes $0{\cdot}9p$, or again $p + 0{\cdot}25$ inch. The mean thickness of the rims is $0{\cdot}45p$.

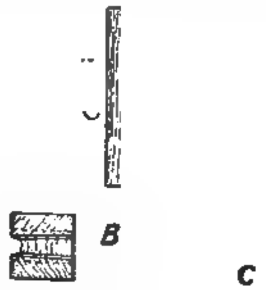


Fig. 230.—Mortice Wheel Patterns.

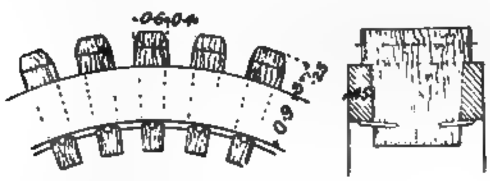


Fig. 231.—Mortice Wheels.

The teeth are always cut with the grain running radially, or in the direction of the length of the teeth. The taper necessary for driving is rather arbitrary. It must not be in excess, nor must the shank be too thin or too thick; the first would render the shank weak, the second would weaken the rim. Good proportions are: the thickness under the tooth $0{\cdot}5p$, and at the extreme end $0{\cdot}45p$. The shouldering in the direction of the width ranges only from about $\frac{1}{8}$ in. to $\frac{1}{4}$ in. in smaller and larger wheels.

The tooth shapes of mortice wheels are generally obtained on a cycloidal basis; frequently, however, the roots are cut parallel, being practically as good as though curved correctly. There is no risk then of short grain splitting out, neither can shoulders form next the roots, as the iron teeth wear away the wooden ones. *See also* **Cogging Wheels,** and **Mortice Wheel Patterns.**

Morticing Machine.—Used for cutting out slots or mortices in wood, by the action of a reciprocating chisel, which is operated in a vertical slotting type of machine, on the table of which the timber is clamped and fed longitudinally. The hand machines are worked by a pivoted lever which draws down the spindle

holding the chisel, the lever being balanced to automatically raise the spindle after each stroke. A boring spindle is located alongside in the more complete machines, to prepare the holes for the chisel. Automatic travel is fitted to the table in the heavier machines, for cutting long slots. The power-driven spindles are actuated by a crank-disc and connecting rod. The graduated stroke types have an arrangement of connecting rods, by which an increasing stroke is gradually imparted to the spindle, on the depression of a treadle. When the chisel is out of the stuff it remains at rest, only coming into action on the movement of the treadle. As the latter is depressed still more the stroke lengthens, and the result is a smooth action without jar. For hub morticing, a dividing arrangement is placed on the table to carry

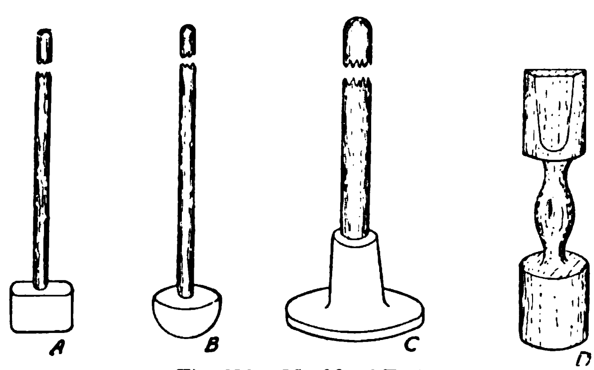


Fig. 232.—Moulders' Tools.

the hubs, and rotate them into accurate subdivisions.

Some small morticing machines are of horizontal type, comprising a horizontal sliding head, and an adjustable rising and falling table, upon which the wood is clamped. *See also* **Chain Mortising Machine.**

Motion Bars.—*See* **Slide Bars.**

Motion Work.—Relates to the rods, links, &c., connected with the slide-valves of engines.

Motor. — Any prime mover; specifically applied to electric motors and petrol motors, described under their headings.

Motor, Electric.—*See* **Electric Motor, Dynamo.**

Mottled Iron.—*See* **Cast Iron.**

Mould.—Specifically a matrix of sand or other material into which molten metal is poured. Also applied to types of moulds other than those for castings, and to dies.

Moulder. — The craftsman who prepares moulds in green or dried sand for the casting of metal into. The work has become highly specialised, so that no single workman now operates in the different classes of moulds and of metals and alloys. The main departments will be found discussed under their proper heads.

Moulders' Tools.—These, with the exception of the rammers and vent wires, operate like the modellers' tools, by a moulding as distinguished from a cutting process.

Rammers.—These are of two kinds, *pegging*, and *flat*. The pegging rammer, Fig. 232, is generally of small dimensions, and either oblong in plan, A, with a convex end, or semi-globular, B. It is held in a short handle for work done when kneeling on the floor, or standing at a bench; or in a long handle, as when standing over floor work. Its function is to consolidate the sand adjacent to the pattern in detail, and particularly into corners and around projecting parts. The flat rammer is of larger dimensions, and flat ended, C. It is used for levelling and consolidating broad areas, and follows the pegging, after box filling. A double-ended rammer, pegging and flat at opposite ends, D, is made in wood and in metal.

Vent Wires.—Pointed rods, Fig. 233, A, B, ranging from $\frac{1}{16}$ in. to $\frac{3}{8}$ or $\frac{1}{2}$ in. diameter, and used for piercing sand after ramming with vent holes, through which the gases escape at the time of casting. The smaller are a few inches long only, the longer 3 or 4 feet.

Trowels.—These, Fig. 233, C to E, are used for many purposes. Their principal function is sleeking flat surfaces, as in making joints between box parts. They cut and shape by their edges, and smooth by their faces. Broken edges are pressed down with the trowel, and joint edges in dry sand are finned. The insertion of a trowel gauges an opening in a box joint. Joint lines are marked on boxes, and on loose cods of sand by the edges of the trowel. The forms are the *long heart*, C, the *broad heart*, D, and the *square*, E.

Cleaners, and Sleekers.—These, Fig. 234, include a large number of tools of various shapes which are used for smoothing or sleeking portions of moulds in all kinds of positions.

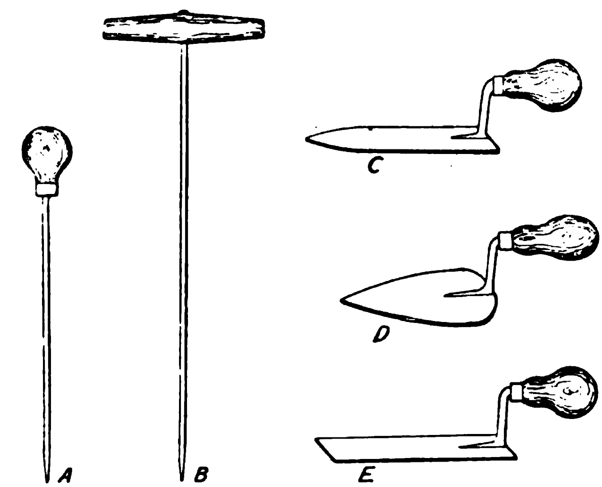
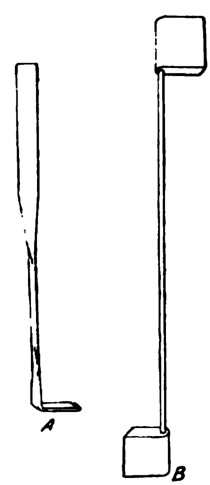


Fig. 233.—Moulders' Tools.

The typical cleaner has a plain flat blade at one end, and a blade turned at right angles at the other, A. Another form has cast ends convex on one side, B. Another has ends turned at right angles, but convex at the back. A large group of smoothing tools are named from their special functions; as *boss* tools, denoting the two cleaners just named. Another is a *flange bead*, because curved to suit the edges of flange moulds. The opposite ends have different curvatures. *Square corner sleekers* are used for smoothing internal angles, C, and external angles, D; E is for curved work; F has a small radius. *Round corner sleekers* or hollow beads, J, smooth external curves. *Pipe smoothers*, G, smooth internal curves, as well as the moulds of pipe bodies. *Button*, or *Bacca box* sleekers, H, are curved in directions at right angles for smoothing moulds of globular section.



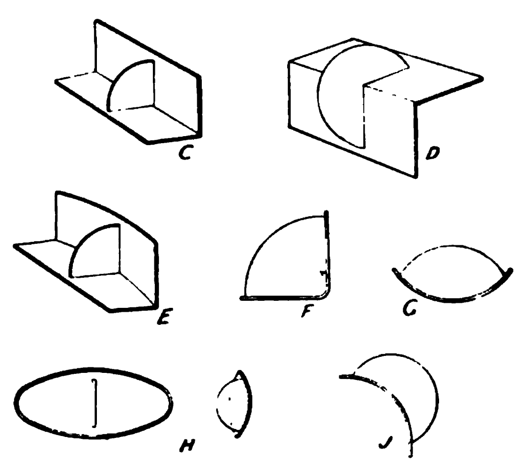


Fig. 234.—Moulders' Tools.

These tools are made in brass and steel. They are carried in a small box with a cross handle, and in the pocket of the moulder.

Moulding.—See descriptions of this work under specific heads, as **Brass Founding, Iron Founding,** &c.

Moulding Box, or **Flask.**—The frame which contains a sand mould for casting into. It occurs in diverse forms and dimensions. Iron is mostly used for boxes, but in Canada, and in some parts of the United States where timber is plentiful, that is commonly employed.

Moulding boxes comprise one or more *parts*. The simplest is a *plain top*, or *cope*, Fig. 235, A, which covers a mould that is contained wholly in the floor, and is formed by bedding-in the pattern. The terms *cope* and *drag* are synonymous with *top* and *bottom*. But cope has generally been restricted to loam work only. The next is a *two-part* box, comprising top and bottom, A and C, Fig. 235, and enclosing a mould that is made usually by turning over. A portion of the mould may be in the top and another in the bottom, or wholly in the bottom, the top being plain. The next comprises a top, bottom, and *middle*, Fig. 235, B, or middles, used when more than one joint in the mould is necessary. These moulds may or may not be made by turning over. The various

parts are registered together by means of pins, and holes in lugs, the positions of which correspond in the matching parts.

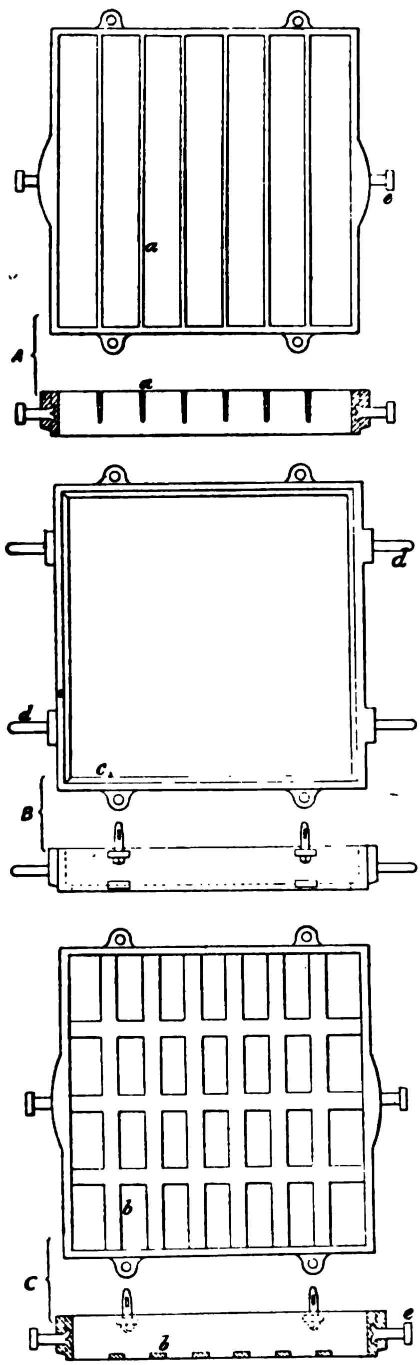


Fig. 235.—Moulding Boxes.

The forms of boxes in plan are varied to suit work of different classes and sizes. The commonest are square, and oblong; many are circular, a limited number are made of special shapes with the object of economising sand space. Thus, pipe and column boxes often have one or both ends wider than the main body. For the same reason the sides are bevelled in cross section. Boxes tapered lengthwise are common. Boxes for bend pipes are formed like two arms meeting at right angles.

The dimensions of boxes vary from about 12 inches square to as many feet square, or long. Many column, and hydraulic cylinder boxes are of greater length. Increase in size involves liability to spring, and difficulty in handling and turning over, so that some very large work is made by bedding-in, and covering with two or more plain tops.

The sand is retained in boxes by *bars*, or *stays*, Fig. 235, *a*, *b*. Generally these are cast flatwise in bottoms, C, and edgewise in tops, A. The latter may be straight, or cut to follow the pattern outlines. Middles seldom have bars, because they would generally encroach on the pattern, and mould space. Internal ribs, *c*, are cast round the edges to retain the sand, and rods are laid on the ribs, and lifters on the rods.

Boxes are lifted by handles, *d*, in the smaller sizes by hand, in the larger by the crane. They are turned over by means of swivels, *e*. Looped handles are often cast in, to assist in turning over by. Back plates are required in deep casts poured in the pit, and flanges are cast on the backs of such boxes to bolt the plates to.

The joint edges of boxes should be planed, the pins turned, and holes drilled and reamered. Badly fitting boxes are a common source of waster castings, or if not these, of castings with lapping joints and fins.

Generally moulds are poured with the boxes flatwise, the exceptions being those poured on end, as when sound metal is required in cylinder work, and in much brass-founders' work. One of the modern types of brass moulders' boxes is shown in Fig. 236, with the holes at one end, through which pouring is done. The vee shapes of the sides retain the

sand without the use of bars. The ribbing of the sides will also be noticed.

Of late years the snap flasks have come into wide use for the smaller repetitive class of moulding. These are hinged at one corner, and opened after ramming, leaving the mould on a bottom board, in which state it is poured.

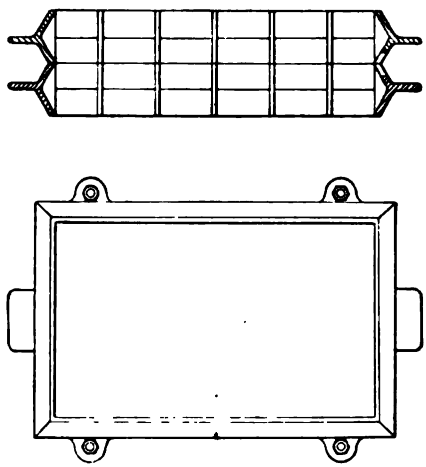
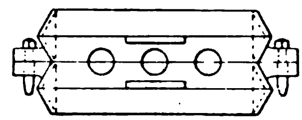


Fig. 236.—Moulding Boxes.

Moulding Machines.—It is difficult to make a classification of these machines, because the examples are so numerous and varied. A convenient division would be that into those requiring hand ramming, power ramming, fixed, and portable types. The great majority of machines are of hand-ramming type, and fixed; power ramming has been gaining ground, but it has its limitations, to be noticed presently.

Hand Machines.—These are of all types with regard to their mechanism, but have this alone in common, that the ramming is done in the ordinary way by the pegging and flat rammers just as in ordinary moulding. But generally a pressure board is included in machines, against which the final squeeze of the sand takes place. Such machines are suitable for any moulds, but they show to best advantage in those which are deep, and in which the sand varies in depth, and where some parts must be rammed harder than others. There is a sensitiveness of touch acquired in hand moulding, without the exercise of which moulds of the kinds just named are often faulty.

Power Machines.—Generally power ramming is applied to the heavier class of machines, otherwise examples are found under all types. The agent used is mostly hydraulic pressure, and after that steam, or compressed air. The thrust is direct, the ram coming up underneath the table, and pressing the mould against the resistance of the presser plate above. This is suitable for patterns that are not very deep, or of very irregular contour; in which case the pressing results in sand too loose in some parts, and too hard in others. It is then essential to make the face of the presser plate of an irregular contour, corresponding approximately with that of the face of the pattern, but in the opposite direction. The back of the mould can then be filled and pressed with a flat presser.



Fixed v. *Portable Machines.*—The first are fixed to foundations similarly to machine tools. All the appliances and materials required are brought to them. Provided tracks, or a conveying system of some kind is used, these machines are suitable. But in their absence moulds have to be carried away, and laid down on the floor for casting. In plain work, *i.e.*, that which does not involve much coring, the output of machines is so great that a large floor area is soon covered. But if a machine is portable on wheels, it can be moved ahead, leaving the array of moulds accumulating behind it. A relatively small number of machines of light construction are therefore made thus.

Examples of Machines.—Samuelson's hand machine is capable of taking boxes up to 18 in. long by 15 in. wide, and is in every respect suitable for light repetition work where a deep lift is not required. The illustration, Fig. 237, shows the machine with the boxes ready for pressing the last box. In bringing over the lever at first, the press plate is moved rapidly over the top of the box, and upon a further application of power to the lever, a vertical downward movement is obtained which presses the mould.

The process is as follows:—Snap flasks or ordinary boxes are used, with ordinary, or *spray* patterns. The oddside is first put upon the table,

and the spray or pattern laid in the same, the bottom box is then put on to the oddside frame and filled with sand; a loose mould board is then dropped on top of the sand, and the iron platen is brought over the top of this by means of the hand lever, the first movement of which brings the platen into a vertical position as above described; and upon a subsequent movement downward of the hand lever, the platen is brought downwards and presses the loose board into the box, compressing the sand accordingly.

boxes will come away, leaving the complete mould standing on the bottom plate, ready for putting on to the foundry floor, a loose rough wood frame being put round the mould to hold it together if necessary. Parted boxes are used for economy and handiness, but of course ordinary iron moulding boxes can be as readily employed.

An excellent example of a hand moulding machine for general work is that by Darling & Sellers, Ltd., seen in Figs. 238 and 239, Plate XVI. It is made in a large range of dimensions

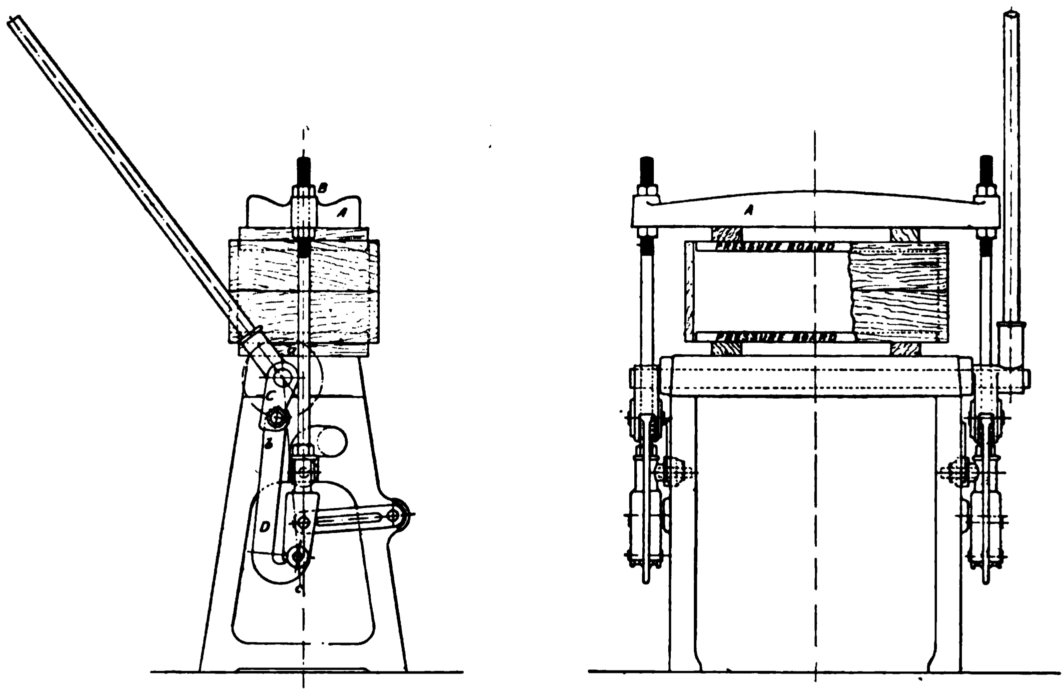


Fig. 237.—Hand Moulding Machine. (Samuelson & Co., Ltd.)

When this bottom box is made, a loose board is put on the top, and it is then turned over on the table, and the oddside lifted from it, leaving the spray in the sand. The top box is then put upon the bottom box, sand filled in, the loose mould board put on the top and the process repeated with the lever and top pressure plate. The pattern is loosened in the sand in the ordinary way, and the top box lifted; then the pattern or spray is taken out, and the box is put together again, after which the fastenings at the corners are unfastened, when the two

for general work, for deep work and stripping plates, with some corresponding differences in details. Fig. 238 is a 30-inch machine, shown moulding axle boxes, and operated by hand-wheels. Fig. 239 shows a 36-inch machine, in which the elevating gear is actuated by a lever. No special pattern plates are necessary, but any patterns of suitable dimensions can be moulded on the table, which is of the turnover type. The standards of these machines between which the mechanism is carried are spaced at various distances apart, ranging from 30 in. to 16 ft.

PLATE XVI.

Fig. 239.—Moulding Machine. (Darling & Sellers, Ltd.)

Fig. 238.—Moulding Machine. (Darling & Sellers, Ltd.)

Fig. 242.—Four-Spindle Drilling Machine.
(John Stirk & Sons.)

Fig. 243.—Eight-Spindle Drilling Machine.
(Pratt & Whitney Co.)

To face page 216.

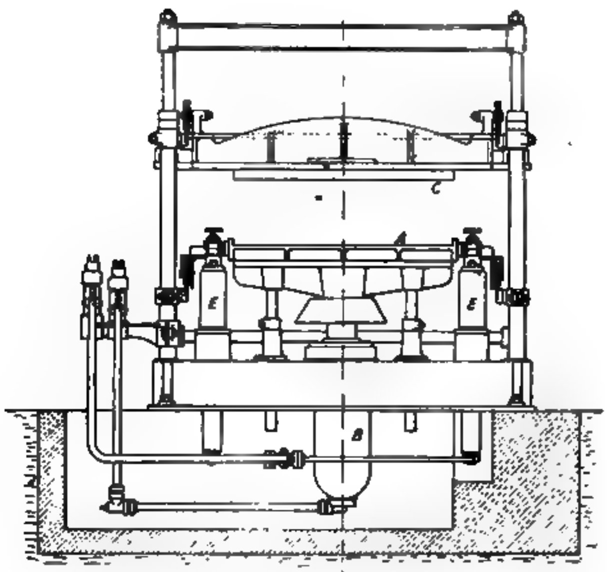


Fig. 240.—Machine for Moulding Cores. (London Emery Works Co.)

Fig. 241.—Hydraulic Moulding Machine.

The pattern is fixed to the upper face of the table, and the moulding box placed over for ramming, and retained in place by means of screws and sockets to suit boxes of different depths, or by spring clips. The table is locked level, and after one side is rammed it is turned through half a revolution and relocked for the purpose of bringing the lifting table, actuated by levers and slotted links and counterbalanced, up against the back of the box part just rammed. The clamps are released, and then lowered, taking away the mould from the pattern, after which it is taken away on a carriage running on the receiving rails. The empty carriage is next run back on the lifting table, and the turnover table is revolved to bring the pattern on its upper face ready for the next box part.

It is impossible to give accounts of the large numbers of excellent machines made. The principal are the Farwell, the Pridmore, both in several types, the Atkinson, the Maywood, the Tabor, many by the London Emery Works Co., the Riches, the Leeder, the Teetor, and German machines by Sebold & Neff, the Gritzner Co., Bopp & Reuther, and others.

A hydraulic moulding machine, designed for moulding cores, by the London Emery Works Co. is shown in Fig. 240. It is of the revolving pattern plate type, A. The ramming is done by power by a ram in the cylinder B, pushing against the presser head C. The moulding box is carried on the trolley D, and the pattern plate is lifted off it by the small flanking rams E, E. This design is suitable for the heaviest machines, taking boxes from 5 ft. to 6 ft. square.

Fig. 241 illustrates a hydraulic moulding machine by the Maschinenfabrik Gritzner A. G., of Durlach. The drawing is largely self-explanatory. The machine has two travelling pattern tables A, A, between which the hydraulic moulding press is placed. The tables each take one-half pattern with its box B. The box which is away from the press is filled with sand, while the other is being rammed. Ramming is done by bringing the ram upwards under the box, followed by withdrawal. This is effected by releasing the pressure, and allowing the ram to descend, so withdrawing the pattern. Having two boxes on the tracks, one ram with its consumption of water is saved.

Moulding Sands.—*See* **Sands.**

Moulding Tub.—*See* **Brass Founding.**

Mouth Piece, or Stand Pipe.—The cylindrical piece which is riveted to a steam boiler to form the body of a manhole, or blow-off cock, or safety valve. In the old practice mouth pieces were not used, the fittings being attached to the boiler shell direct. The use of cast iron and cast steel has generally given place to that of mild steel rings, bent, welded, and flanged. *See* **Manholes.**

Mowing Machines.—These comprise a pair of road wheels carrying a shaft, which supports a swing beam to which the horse or horses are hitched. A projecting arm beneath the beam supports a cutter bar standing out laterally, and passing over the ground by means of small rollers. This bar serves to carry a long knife which is reciprocated by a crank driven through bevel gears and shafts from the road axle. A finger bar is placed above the knife and holds a number of steel-plated fingers which enable the knife to do its work. Levers connecting to the attendant's position, in a seat at the rear of the axle, enable him to lift the finger bar over obstacles, or when turning corners, and another lever provides for tilting the fingers, to suit the conditions of cutting. The usual width of cut is 5 ft.

The gearing in such machines is enclosed as far as possible by running the shafts in tubular supports, and encasing the gears, and ease of running is ensured in the best machines by fitting roller bearings to the shafts. The road wheels are either of cast iron or of steel, with plate rims, and biting irons or ribs are placed on the periphery.

Mud Holes.—The holes in the shells of steam boilers through which deposit is raked out periodically. They measure about 5 in. by 3 in. Being so small they are not reinforced with strengthening rings. The door is a casting, a forging, or a stamped steel plate, the latter being best. The bolt is tightened against a bridge piece which is a forging.

Multiple Moulding.—A system of moulding by machine in which top and bottom box

parts are so arranged in series that several similar moulds are superimposed, and poured from a common ingate that runs from top to bottom of the series.

Multi-Spindle Boring Machine.—The chief object in having more than one spindle in a boring machine is to bore out two or more holes at a setting, the advantage being greatest when repetition work is done, the centres of the spindles being fixed. There is a good deal of this in duplex pump and cylinder work, bearings, and similar objects, and the time thus saved is very considerable. Spindles are set with their axes parallel to each other, or at angles, and the centres are fixed, or variable, according to the character of the operations. Some of the most complete machines are those designed for dealing with Corliss cylinders, boring out the four valve chambers simultaneously. Another type used by engine builders has bars set at right angles, one boring out a cylindrical crosshead guide, the other the crank-shaft bearings in an engine bed.

Multi-Spindle Drilling Machine.—The capacities of drilling machines are increased enormously by multiplying the number of spindles, from two up to several dozens, to drill holes either in separate objects, or all in a single piece. Designs are varied, according to whether all the drills have to be fed simultaneously, or independently. The latter method is followed when different sizes of drills and classes of work are dealt with, thus leaving the operator a choice of feeds, but in dealing with such work as flanges, having a ring of uniform holes, the feed is simultaneous to all. Two-spindle machines are employed chiefly for dealing with such work as connecting rods and tie rods, levers, &c., having holes at each end; the general design is that of uprights with a cross-rail upon which the drill spindle saddles are adjustable above the table lying between and in front of the uprights. The type is also made with more than two spindles, especially for bridge and girder work, and framings of various kinds, such as for trucks.

Fig. 242, Plate XVI., shows a four-spindle machine. The spindles are carried in bearings that are adjustable along a cross-rail, and may be clamped thereto by bolts. The spindles are fed down by hand levers, or automatically by a power feed derived from a shaft running within the cross-rail. The driving is effected from another shaft above the cross-rail, and the choice of four speeds is available. The table, adjustable vertically and laterally by handles and screws, is supported upon flat ways on the faces of the columns.

Horizontal machines are made to a limited extent, principally for rail drilling, where the traverse of the drills is short. The heads are mounted on a slotted table, and face each other, the work lying between them.

A class of machine that is very much used for drilling geometrical figurings of holes in parts that have to be bolted together, such as valve bodies, flanges, pipes, cylinders, &c., has the spindles driven by shafts coupled at the ends by universal ball joints, thus permitting the drilling ends to be shifted about to suit any pattern required. They are clamped by slotted bars, embracing their lower bearings, to a common plate. The feed is imparted by moving the head bodily, or by raising the table with the work upon it.

The latter method is shown in the photo, Fig. 243, Plate XVI., having both hand and self-acting feeds. The weight of the table is counterbalanced.

Muntz Metal.—An alloy of three parts of copper with two of zinc. Being highly ductile it is used for bars, sheets, and tubes. It can be forged hot, and hardened by hammering or rolling. It has a tensile strength of about 22 tons.

Mushet Steel.—A self-hardening steel which owes its property to the presence of a large proportion of tungsten. It contains from about 5 to 8 per cent. of tungsten, and about 1·5 to 2·3 per cent. of carbon. It is heated and cooled in air instead of being quenched in water like the carbon steels, the tungsten imparting the hardening property. Its invention was due to R. F. Mushet in 1868. It has long been in use in the turnery and machine shop when heavy and severe cutting have had to be done. To some extent its value has been eclipsed by the high-speed steels, but not to a very serious extent. There are many records of heavy work, and endurance of Mushet tools doing

work at a red colour, at speeds and feeds equal to those of the newer tools.

Mushet steel is made in six various tempers, most of which can be welded. No. 2 is suitable for boiler snaps, hammers, dies, and numerous drills. It welds easily. No. 3 is suitable for large chisels, cold setts, and smiths' tools, also for large shear blades, dies, and miners' drills. No. 4 is used for cold chisels, hot setts, punches, large taps, reamers, and milling cutters ; shear blades and miners' drills for hard rock. Nos. 3 and 4 may be welded with care. No. 4½ is used for taps, reamers, milling cutters, screwing dies, punches, shear blades, large drills, and turning tools, mill picks, and spiral springs. It may be welded with great care. No. 5 is the most useful for drills, turning, planing, and slotting tools. It is suitable also for small taps, reamers, cutters, and screwing dies. It will not weld. No. 6 is the most suitable for small turning and planing tools, engraving tools, small drills, and razors. This temper must not be overheated.

Mushet steel is forged after being soaked gradually to a yellow heat, it must not be worked below a red heat. It is hardened by reheating the cutting end to a white welding heat, and immediately blowing cold. If an air blast is not available, oil may be used. Plenty of water must be used in grinding, which must be done thoroughly, preferably on sandstone.

Mushroom Valve.—The common annular lift valve, with three or four guiding wings fitting an annular seating.

Mutilated Gears. — *See* **Intermittent Gears.**

N

Name Plates.—These are cast as separate plates, and bolted to machinery, or they are cast on solidly, to prevent risk of their removal and the substitution of another plate. Name plates are moulded from patterns of wood and of metal, and they occur in all dimensions, from letters of ½ inch in height to those of 3 inches or more.

Formerly letters cast in lead or tin were commonly used, filed up, and cemented or nailed on a pattern of wood with a bead round the edge. Lead letters are readily distorted, and they are heavy. Those of brass are better. These are supplied to the trade in different designs. Except in the smallest sizes they are hollowed at the back, with reduction in weight, and metal. Holes are drilled to receive tiny tacks, but previous cementing is also desirable, for which thick shellac varnish is used to which a little powdered chalk is often added. The best letters are those of block form, "sanserif," because they mould easier than ornamental ones. These are made in ordinary proportions, and also in tall narrow types for use where space is limited. Metal pattern plates are cast from those of wood and filed up. If name plates have to be curved to fit round sweeped parts, a pattern is cast in lead or soft brass and bent, and the actual castings made from the latter.

If name plates are cast on machinery the letters are attached to the pattern by the same method as to a separate plate, provided they can be moulded to lift, or draw with the pattern. But if not, as when moulded on the side, a core print is put on the pattern, corresponding in size with the name plate required, and the actual plate is put in a core box, on a bottom board, and the core inserted. This plan is adopted sometimes even when the letters would lift with the pattern, because there is less risk of fracture occurring, and the core can be dried.

Nails.—Nails are very commonly used in wood-work. They hold parts together by the compressive force and friction which the material into which they are driven exercises on them, thus making it difficult for the parts to move in relation to each other, or the nail to be withdrawn. They are driven with a hammer till their heads are flush with the surface of the material, and in some cases are afterwards punched below the surface. Sometimes holes are bored for them, and sometimes not, according to whether or not there is risk of their splitting the wood. In nailing thin material together the nail points are sometimes allowed to come through and be clinched, that is, bent over at right angles and hammered flush.

Some of the common forms of nails are shown in Fig. 244. There are innumerable variations in detail. In size, nails range from about ¼ inch

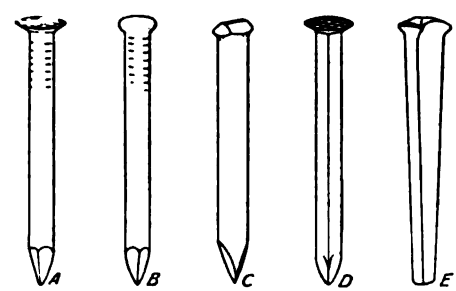


Fig. 244.—Nails.

in length up to 6 inches or more. In diameter they vary also according to the work they are required for. The larger kinds are called spikes. Various names are given to nails to distinguish one kind from another. When of wire they are frequently called pins. Wire nails are now the most commonly employed. They are parallel, with pointed ends and with heads of various shapes. The most popular form for medium and large sizes is that shown at A. Its head is flat, and about twice the diameter of the body. The latter is slightly nicked near the top to increase its hold. B has a smaller head which is better for punching in, and less conspicuous.

This form, and slight variations from it, is generally adopted for small nails. C is an oval nail, and D a square one, neither of which are used as much as cylindrical. E is known as a cut nail, and is used chiefly in large sizes; it is not of wire like the preceding ones, but is cut generally tapering one way, and parallel the other. Numerous other kinds of nails are employed for special purposes.

Napier's Bones.—An ingenious invention of the famous mathematician, John Napier (1550-1617), which considerably simplifies the processes of multiplication and division, and would have been extensively used but for his discovery of logarithms. A series of ten bones, strips of ivory, cardboard, &c., are inscribed in the same way as that for the number 5 in Fig. 245. It will be noticed that the pairs of figures

in the rectangles are multiples of 5 up to 9 × 5, or 45.

Now suppose it be required to multiply 65108 by 3726.

Arrange the bones or rods for the number 65108 side by side. The unit's figure of 3726 is 6; count down to the sixth row of multiples where the following figures are seen :—

```
 60608
33004
```

Add these two lines up mentally and put down the total. Next add up the second, seventh, and third rows, and the total product is found:—

```
    65108
     3726
   ------
   390648
  130216
 455756
195324
---------
242592408
```

Naval Brass.—Consists of three parts of copper and two of zinc—Muntz metal—with about 1 per cent. of tin added. It has the power of resisting the action of sea water, and is used for the bolts which are exposed to the action of sea water in ships of war. It can be forged hot, and bent double when cold. It is rather stronger than Muntz metal.

Navvy.—*See* **Excavator.**

Needle Lubricator.—*See* **Lubricators.**

Nernst Lamp.—A radical departure from the ordinary carbon filament lamp, due to Professor Nernst. He found that certain oxides of metals, which include some of those

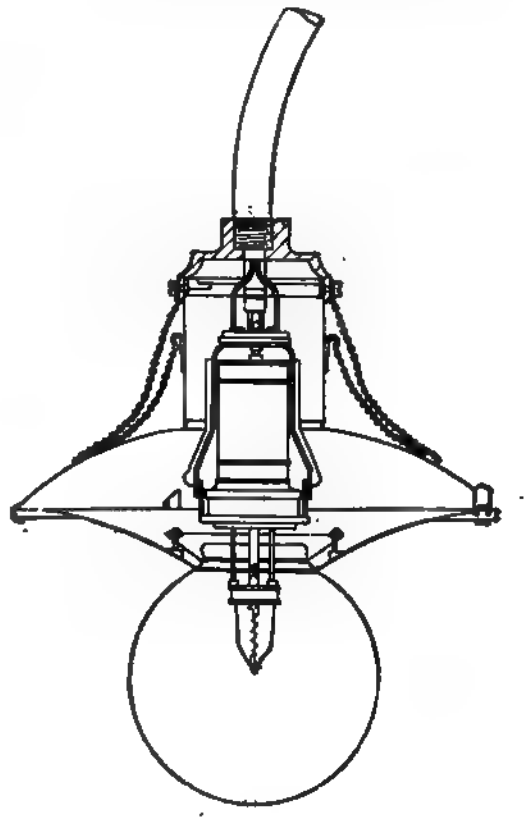


Fig. 246.—Nernst Lamp.

used in the manufacture of incandescent gas mantles, become good conductors of electricity when heated to from 600° to 800° Cent., although they are non-conductors at ordinary temperatures. The lamp as now made, includes the filament, the heater, the automatic cut-out, and

the resistance. The heater coil, Fig. 246, surrounds the rod or filament, and when it has been in circuit for a few seconds the filament becomes hot enough to conduct, after which the automatic cut-out comes into operation, and cuts out the heater coil. The resistance protects the filament from variations in the voltage, which have a destructive effect upon it. The light emitted is of a pure white character, and as there is no necessity to maintain a vacuum in the globe, replacement of parts is simple, and does not necessitate throwing away the whole lamp. The Nernst lamp gives a light of one candle for a consumption of 0·9 to 1·7 watts.

Neutral Axis.—*See* **Beam.**

Newel.—The column or post around which a winding staircase turns. Also the main posts which support the balustrading of any stairs.

New Zealand Pine.—*See* **Kauri Pine.**

Nickel.—Ni, 58·7; sp. gr., 8·28 (ingot), 8·66 (forged); melting point, 1,450° Cent.; specific heat, ·1086; coefficient of expansion by heat, ·00000695; weight in lb. per cubic ft., 540 (forged), 517 (ingot); weight in lb. per cubic in., ·31 (forged), ·30 (ingot). Nickel occurs as arsenide, NiAs (kupfernickel), as silicate, with cobalt in speiss, in magnetic pyrites, &c. It is a white, malleable, ductile, lustrous, and very tenacious metal.

Nickel is of chief importance in the formation of alloys, more especially **German Silver,** which is an alloy of copper, zinc, and nickel. Cupro-nickel (75 parts copper and 25 parts nickel) is used for coinage, and in the manufacture of projectiles (80 parts copper, 20 parts nickel). **Nickel Steel** is used for armour plates.

The properties mentioned above make nickel one of the most valuable metals for electro-deposition, this being generally done from a solution of nickel ammonium sulphate which has been rendered neutral to litmus.

Nickel Steel.—Nickel alloys with iron in all proportions. Many experiments have been made on the physical properties of steel containing up to about 50 per cent. of Ni. Commercial grades range from 3 to 30 per cent. of Ni. It is used largely for heavy forgings, and with chromium for armour plates. If Ni is present to more than 1 per cent. welding is difficult. Nickel steel shows increasing strength and higher elastic limits until 20 per cent. is reached, at which these are at the maximum. Its elongation and reduction of area do not suffer with the increase in strength as is the case with ordinary mild steel. It is therefore often possible to reduce the weight of forgings without sacrifice of strength.

Nitric Acid.—Or aquafortis, HNO_3; sp. gr., 1·530; boiling point, 86° Cent. This acid is obtained by heating nitre, KNO_3, or saltpetre, $NaNO_3$, with sulphuric acid:—$KNO_3 + H_2SO_4 = HNO_3 + HKSO_4$, or $2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3$. The heating is done in cylinders or retorts of cast iron, for though dilute nitric acid dissolves iron, it has no effect on the metal when strong. The acid distils over and is condensed in a series of earthenware bottles (Woulff's bottles), which are connected by corkscrew-shaped earthenware tubes surrounded by cold water. The first bottle condenses any sulphuric acid that passes over, the temperature being too high for the condensation of nitric acid.

It is a colourless, strongly fuming caustic liquid with a very pungent odour. The presence of lower oxides of nitrogen gives the acid a yellow tinge. It is also very hygroscopic. Nitrogen parts with some of its oxygen readily and so is useful as an oxidising agent.

Nitric acid is recognised by the properties mentioned above; by its action on metallic copper or tin, yielding red fumes; by its bleaching action on indigo; and by the delicate and pretty test of adding to the liquid to be tested an equal volume of strong sulphuric acid, and when cool, pouring on a solution of sulphate of iron; an unmistakable black (or brown if only a small quantity of HNO_3 be present) ring is seen where the two liquids meet.

HNO_3 is extensively used in various trades and manufactures. It is largely employed in the preparation of various explosives. When carbolic acid, C_6H_5OH, is acted on by nitric acid, picric acid, $C_6H_2(NO_2)_3OH$, is produced, and this latter compound enters largely into the manufacture of **Lyddite,** as well as being used as a yellow dye for fabrics. Benzene, acted on by HNO_3, produces nitro-benzene,

$C_6H_5(NO_2)$, which is reduced to aniline, $C_6H_5(NH_2)$, used in aniline factories for the dyeing of silk, calico, and woollen fabrics. The action of HNO_3 and H_2SO_4 on glycerine produces **Nitro-Glycerine,** $C_3H_5(NO_3)_3$, which when absorbed by kieselguhr is called **Dynamite**. **Gun-Cotton,** $C_{12}H_{14}O_4(NO_3)_6$, is produced by the action of strong nitric acid upon cellulose. Nitric acid is also used in the separation of gold and silver from their alloys, and for etching and engraving.

Nitrogen.—N; density, 14·04. An element present in the atmosphere, of which it constitutes four-fifths of the total bulk; it is an essential constituent of animal and vegetable organisms, and of several chemical compounds. This gas, which is neither inflammable nor a supporter of combustion, is colourless, inodorous, and light, its specific gravity being ·96. It liquefies at about − 195° Cent., and solidifies at about 213° Cent. Nitrogen is an inert element, refusing to combine readily with other substances, and generally speaking its compounds are rather unstable. With oxygen it forms five oxides—nitrous oxide (N_2O), nitric oxide (NO), nitrous anhydride (N_2O_3), nitric peroxide (N_2O_4), nitric anhydride (N_2O_5); with hydrogen it forms ammonia (NH_3); with oxygen and hydrogen, nitric acid (HNO_3).

In its liquid form nitrogen is colourless and mobile, and produces a greater lowering of temperature on evaporation than liquid air. When poured over a bulb of oxygen the gas becomes condensed on the inside of the glass in bluish drops. Poured over metallic calcium it forms calcium nitride, and on treating this with water, ammonia is given off.

Nitro-Glycerine.—Also called propenyl nitrate, and nitro-glycerol, $C_3H_5(NO_3)_3$, is obtained by the action of nitric and sulphuric acids on glycerine. It is essential that both acids and glycerine should be quite pure. The mixed acids are placed in a leaden vessel, and the glycerine added slowly, the temperature being kept below 30° Cent. by cooling worms. A second apparatus separates the nitro-glycerine, which then goes through several washings and filtrations.

Nitro-glycerine is colourless when pure, odourless, possesses a sweet and burning taste, and is poisonous. Sp. gr. 1·6 at 60° Fahr. It freezes at about 46° Fahr., but is not generally used either in the liquid or frozen state owing to the greater convenience of use when mixed with some absorbent material such as kieselguhr. In this form it is called **Dynamite**. With gun-cotton it forms blasting gelatin. Being unaffected by water, nitro-glycerine is useful in sub-aqueous work, and was largely used at Hell Gate or Flood Island, in Long Island Sound, New York.

Nitro-glycerine requires to be fired by the sudden application of high temperature, and pressure, and so is always ignited by means of a detonator. This is a thin copper tube closed at one end and filled with fulminate of mercury and potassium chlorate, and the fuse is inserted through the open end of the tube in the fulminating mixture, being held in place by pinching together the open end of the tube. *See* **Blasting**.

Nonagon.—A nonagon is a polygon with nine sides. For its geometrical construction, calculation of area, &c., *see* **Polygon.**

Non-Conducting Coverings.—The importance of these increases with continued increase in the pressure and temperature of steam employed. Coverings must not only be non-conductors, but also non-inflammable, and infusible, an important proviso. Hair felt, slag wool, and fossil meal are excellent non-conductors. In strictness no substance is an absolute non-conductor, but relatively some are five or six times more efficient than others.

Experiments have been made to determine the relative value of various substances. Those of Professor Ordway made for the Boston Manufacturers' Mutual Fire Insurance Co. are given in the table on the next page. This represents in a graphic manner the relative efficiency of materials which are wholly free from the danger of being carbonised, or ignited, by slow contact with pipes or boilers; (printed in ordinary type) and those which are more or less liable to be carbonised (printed in italics). Each of the non-conductors tested was used in a mass 1 in. thick, placed in a flat surface of iron kept heated by steam to 310° Fahr. The table gives the amount of heat transmitted per hour through each kind of non-conductor

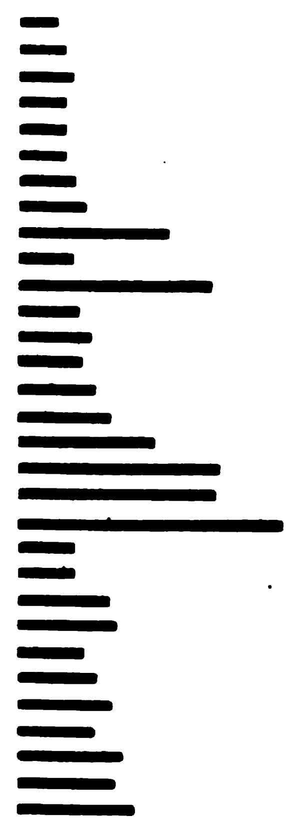
1 in. thick, reckoned in pounds of water heated 10° Fahr., the unit of area being 1 square foot of covering. The value of the non-conducting material is in inverse proportion to the length of the lines. The short lines show a small amount of heat transmitted, the longer ones, larger amounts.

shall not become converted into a solid material by vibration, the effect of which is to render them quick conductors. This applies especially to slag wool. It is necessary that still air shall be entangled, and remain stagnant in the materials. Materials should have rough fibres; for this reason non-conducting power

RELATIVE EFFICIENCY OF NON-CONDUCTING MATERIALS.

No.	SUBSTANCE. One inch thick. Heat applied, 310° Fahr.	Heat Value.
1	*Loose wool*	*8·1*
2	*Live geese feathers*	*9·6*
3	*Carded cotton wool*	*10·4*
4	*Hair felt*	*10·3*
5	*Loose lamp-black*	*9·8*
6	*Compressed lamp-black*	*10·6*
7	*Cork charcoal*	*11·9*
8	*White pine charcoal*	*13·9*
9	*Anthracite coal powder*	*35·7*
10	Loose calcined magnesia	12·4
11	Compressed calcined magnesia	42·6
12	Light carbonate of magnesia	13·7
13	Compressed carbonate of magnesia	15·4
14	Loose fossil meal	14·5
15	Crowded fossil meal	15·7
16	Ground chalk (Paris white)	20·6
17	Dry plaster of Paris	30·9
18	Fine asbestos	49·0
19	Air alone	48·0
20	Sand	62·1
21	Best slag wool	13·0
22	*Paper*	*14·0*
23	*Blotting paper, wound tight*	*21·0*
24	*Asbestos paper, wound tight*	*21·7*
25	*Cork strips, bound on*	*14·6*
26	*Straw rope, wound spirally*	*18·0*
27	*Loose rice chaff*	*18·7*
28	Paste of fossil meal, with hair	16·7
29	Paste of fossil meal, with asbestos	22·0
30	Loose bituminous coal ashes	21·0
31	Loose anthracite coal ashes	27·0
32	Paste of clay and vegetable fibre	30·9

POUNDS OF WATER. Heated 10° Fahr. per hour, by transmission through 1 sq. ft.



The materials may often be mixed and used with safety, though one of the constituents alone may be easily carbonised. Materials must be dry, for still water conducts heat about eight times as rapidly as still air. They must also have some elasticity, so that they is determined less by the nature of the substance itself than by its mechanical texture. If a given quantity is compressed to diminish the thickness of the covering, the efficiency is lessened, because the resistance to the transmission of heat is nearly proportional to thick-

ness. An inch thick is the minimum which should be used, and 2 inches is necessary for large vessels like boilers.

The following table does not coincide entirely with the same substances given in the previous one. But it shows the superiority of slag wool and fossil meal.

NON-CONDUCTING COVERINGS.

SUBSTANCES.	Pounds of water heated 10° Fahr. per hour, per square foot.
Slag wool (silicate cotton) and hair paste	10·0 lb.
Fossil meal and hair paste	10·4 ,,
Paper pulp alone	14·7 ,,
Asbestos fibre wrapped tightly	17·9 ,,
Fossil meal, and asbestos powder	26·3 ,,
Coal ashes, and clay paste wrapped with straw	29·9 ,,
Clay, dung, and vegetable fibre paste	39·6 ,,
Paper pulp, clay, and vegetable fibre	44·6 ,,

classes of work and for timber constructions. It affords a good hold for the spanner, but cannot be turned so conveniently in a confined situation as the hexagon nut, B, because it requires a quarter of a rotation before the spanner can be put on again for a fresh grip, while the hexagon only requires a sixth. The proportions for hexagon nuts are given under **Bolt**; square nuts are the same size across the flats as hexagon ones of similar thread diameter. The convex faced nut C allows a little latitude of movement when parts do not align exactly. The face of the work is sometimes left flat, and a concave washer put under the nut. A flanged nut D is useful to cover up a large hole without the use of a separate washer; it is often employed in conjunction with a leather or other packing beneath to form a tight joint, especially

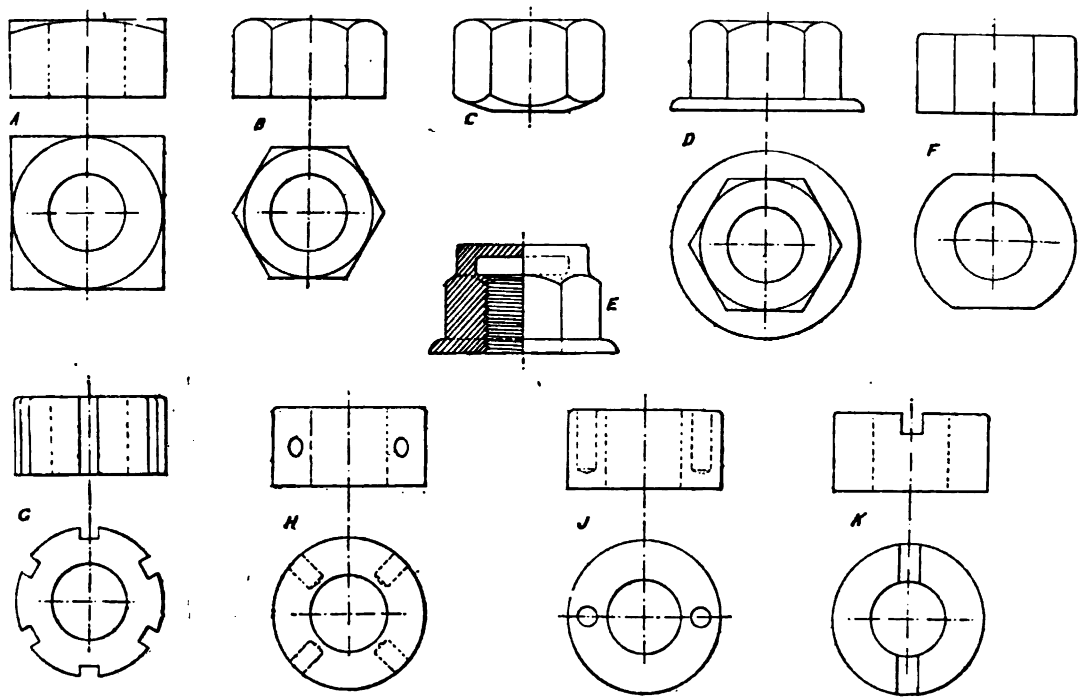


Fig. 247.—Nuts.

Normal Pitch.—The pitch of a screw gear or of helical teeth taken at right angles with the axis of the spiral.

Nut.—Used in combination with a bolt or a stud, as a means of union. The square nut, Fig. 247, A, is used chiefly for the rougher

on pipes. The cap or box nut, E, goes a stage further, the end being closed in, to prevent the end of the screw from rusting, or leakage occurring past the screw. Wing or thumb nuts have a couple of projecting ears which are gripped by the fingers; a good many nuts on

machine tools, and other mechanisms are combined with short handles, to save the time of picking up a spanner, when frequent handling is necessary.

Circular nuts include those with flats F for a spanner, slots G for a hooked spanner, holes for a tommy, being set laterally as at H, or vertically, J, and slots K for a sort of bifurcated screw driver. The last two are only used when it is essential to sink the nuts flush with faces. *See also* **Lock Nut.**

Nut Making.—Nuts are produced either by forging, or by turning from bar. *Black* nuts are those left just as forged, *faced* nuts are turned on the faces, *bright* nuts are shaped or otherwise tooled on the body, in addition to facing, while for the best work hardening is done.

Forging is done from bar, the blanks being punched out, and subsequently trimmed or swaged. The tapping is done in machines of the type described under **Bolt Screwing Machine**, or more expeditiously in special types with several spindles, fitted with carriers which take a string of nuts one after another over long taps. The facing operation is effected on a special type of lathe, provided simply with a headstock, and a rest; the nuts are run on to a short screw mandrel, which is fitted with a spherical washer, that adjusts itself automatically to the nut face, and allows the threads of the nut and mandrel to fit naturally, so that the resulting facing is true with the threads, irrespective of the previous condition of the rough faces. The tooling of the flats is done by shaping, milling, or grinding. When shaped, a large output is secured by mounting a string of nuts on a mandrel between index centres, which brings the flats round in correct positions; some machines have three or four such centres placed under a set of tools, so that several dozen nuts can be treated simultaneously. Milling is best done with straddle mills, embracing two sides at once. Since the advent of disc grinders, much finishing has been done on these, especially in the case of brass nuts.

O

Oak (*Quercus*).—This is the best known and most important of the hardwoods. It grows in nearly all parts of the world and is suitable for almost any purpose. Formerly in England it was by far the most commonly used wood, but circumstances have greatly reduced its importance. First, the home supply became inadequate, and imported oak was found to be of inferior quality. Then imported softwood became popular because it was light, cheap, and easy to work. New varieties of hardwood were imported, and some of them were found equal to or even superior to oak for special purposes. Finally iron and steel is displacing wood altogether for large structural work. Oak, however, must be regarded as the best all round wood that we have, and second to none for durability. Perhaps the most important work it is commonly used for now is railway wagon and carriage building. It is tough, fairly straight grained, flexible, greyish brown in colour, hard, heavy, and rather difficult to work. Boards cut radially from the trunk exhibit grain markings peculiar to oak, and the wood cut in this way is called wainscot oak.

Occlusion.—Relates specifically to the absorption of gases by molten metals. This property they possess in common with fluids. This is the reason of blow-holes in castings. *See also* **Fluid Compressed Steel**. Hydrogen may be occluded by steel to the extent of five or six times its own volume. Nitrogen and CO are also occluded. Apart from the formation of blow-holes, there is no proof that occluded gases exercise any influence on the strength, or physical characteristics of steel. Small additions of ferro-silicon and aluminium prevent, or largely lessen the formation of blow-holes.

Octagon.—A polygon with eight sides. For the mensuration and construction of the octagon, *see* **Polygon**. The following is a particular method of constructing an octagon on a given line AB (Fig. 248):—

Produce AB both ways, and erect perpendiculars AE, BF. Bisect angles CAE, DBF, making AG and BH = AB. Draw GJ, HK parallel to

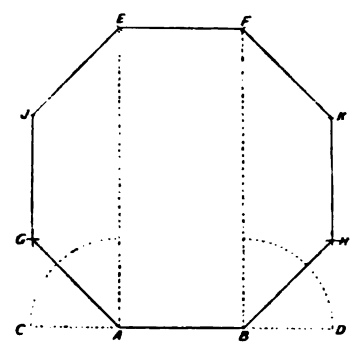


Fig. 248.—Octagon.

AE and equal to AB. With centres J and K, and radius AB, cut AE and BF at E and F. Join JE, KF, EF.

Oddside Moulding.—A method which economises the time of the moulder when a large number of similar moulds are required. It is adopted largely by brass founders, and in a less degree by iron moulders. To explain it briefly, the method of **Turning Over** may be referred to. In this, using a two part box, the pattern is first bedded loosely in the box, which is subsequently to be the top, and the sand is only consolidated sufficiently to allow of a joint face being made on which to ram the bottom box. The temporary half mould, having served this purpose, is knocked out, after being turned over with the bottom, and is re-rammed properly on the bottom to form the real top of the mould. The making of this temporary joint has to be repeated for every mould, and when the joint is not plane it may often involve a good deal of work. Runners also have to be cut in one or both halves.

Now, oddside moulding means that a false or duplicate mould is made on which to ram as many separate bottoms as there are castings required. Afterwards the top is rammed on the bottom as before. The patterns used are unjointed, as are the majority of small brass moulders' patterns. They are laid in the oddside, and the projecting half, or portion rammed. On the removal of the mould (the bottom part) the parts are taken from the oddside, and put in the bottom mould with the other half or portion now projecting for the top part to be rammed on.

The oddsides are made of hard rammed sand only, or of sand hardened and consolidated with linseed oil, or of plaster of Paris. The face is frequently varnished like patterns. Plate moulding and machine moulding may utilise oddsides. The greatest economy occurs when, as in brass founding, a number of small patterns are arranged in a single box.

Odontographs.—Instruments by which the marking out of the forms of wheel teeth is facilitated, the odontograph embodying the application of the principles on which it is based.

The original of the odontographs, and the

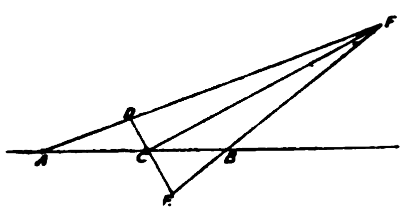


Fig. 249.—Odontograph.

one chiefly used, is that which was designed by Professor Willis. It has for its base the element of a link connecting two arms which move around fixed centres, Fig. 249, the link dividing the line of centres at a fixed point, corresponding with the pitch point. If the connecting link is always normal to arcs struck from its terminations, the curves will move wheels precisely as by the friction of their peripheries. In the odontograph scale, a constant angle is given to the link which cuts the line of centres in the pitch point, and the curves for tooth faces and flanks are taken at the terminations of the link. Thus, Fig. 249, let A B represent the centres of a wheel and pinion, and C the pitch point. Draw

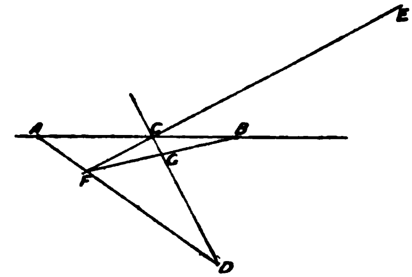


Fig. 250.—Odontograph.

D E making a suitable angle with A B, and raise a perpendicular C F on it. Assume a centre D for the arc of the tooth for wheel A. Join

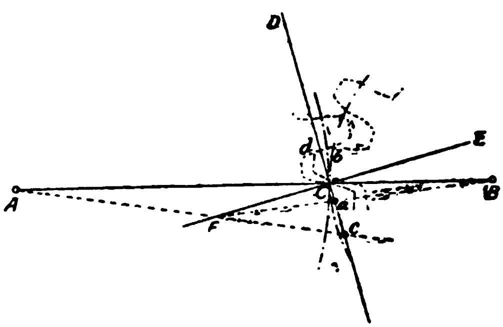


Fig. 251.—Odontograph.

A D and produce to F. Produce F B to E, and E will be the centre for the arc of the pinion tooth. The angle which D E makes with A B

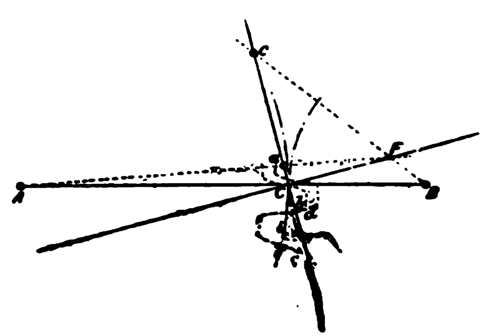


Fig. 252.—Odontograph

cannot be varied widely. It was fixed by Willis at 75°.

The diagram is correct only for single curve

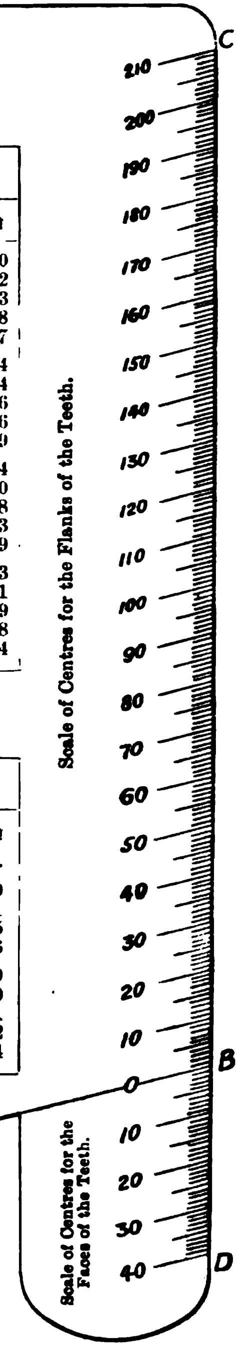


TABLE SHOWING THE PLACE OF THE CENTRES UPON THE SCALE.

Centres for the Flanks of the Teeth.

Number of Teeth.	Pitch in Inches and Parts.													
	¼	⅜	½	⅝	¾	1	1¼	1½	1¾	2	2¼	2½	3	3½
13	32	48	64	80	96	129	160	193	225	257	289	321	386	450
14	17	26	35	43	52	69	87	104	121	139	156	173	208	242
15	12	18	25	31	37	49	62	74	86	99	111	123	148	173
16	10	15	20	25	30	40	50	59	69	79	89	99	191	138
17	8	13	17	21	25	34	42	50	59	67	75	84	101	117
18	7	11	15	19	22	30	37	45	52	59	67	74	89	104
19	...	10	13	17	20	27	35	40	47	54	60	67	80	94
20	6	9	12	16	19	25	31	37	43	49	56	62	74	86
22	5	8	11	14	16	22	27	33	39	43	49	54	65	76
24	...	7	10	12	15	20	25	30	35	40	45	49	59	69
26	...	...	9	11	14	18	23	27	32	37	41	46	55	64
28	4	6	...	...	13	...	22	26	30	35	40	43	52	60
30	...	...	8	10	12	17	21	25	29	33	37	41	49	58
35	...	...	...	9	11	16	19	23	26	30	34	38	45	53
40	...	5	7	...	...	15	18	21	25	28	32	35	42	49
60	3	...	6	8	9	13	15	19	22	25	28	31	37	43
80	...	4	...	7	...	12	...	17	20	23	26	29	35	41
100	...	...	...	...	8	11	14	...	...	22	25	28	34	39
150	...	...	5	...	...	...	13	16	19	21	24	27	32	38
Rack	2	...	...	6	7	10	12	15	17	20	22	25	30	34

Centres for the Faces of the Teeth.

Number of Teeth.	Pitch in Inches and Parts.													
	¼	⅜	½	⅝	¾	1	1¼	1½	1¾	2	2¼	2½	3	3½
12	1	2	2	3	4	5	6	7	9	10	11	12	15	17
15	...	...	3	...	...	...	7	8	10	11	12	14	17	19
20	2	...	...	4	5	6	8	9	11	12	14	15	18	21
30	...	3	4	...	...	7	9	10	12	14	16	18	21	25
40	...	...	...	...	6	8	...	11	13	15	17	19	23	26
60	...	...	...	5	...	...	10	12	14	16	18	20	25	29
80	...	...	...	...	...	9	11	13	15	17	19	21	26	30
100	...	...	...	...	7	...	...	...	...	18	20	22	..	31
150	...	...	5	6	...	...	...	14	16	19	21	23	27	32
Rack	...	4	...	...	...	10	12	15	17	20	22	25	30	34

Fig. 253.—Odontograph.

teeth. For those with double curves, instead of having the point of contact directly on the line of centres, it must be obtained just before and after the line. And as it may happen that the ends of the connecting link may not be on opposite sides of the pitch point, but both on one side, this gives a clue to the convex and concave teeth of the cycloidal types. Thus: in Fig. 250 let A B be the line of centres, as before, and C the pitch point. Assume D as the centre of the arc for the wheel A. Producing D to A will cut the perpendicular of the instantaneous centre E C prolonged at F, and B connected, will give G as the centre of the arc for the wheel B. The arc from G will therefore be convex, and that from D concave.

In the fundamental link movement the arcs struck can only be correct for a single point on the line of centres. But the odontograph makes an approximation by taking two positions at a little distance on each side of that point. One is taken for the concave, and one for the convex face, within and without the pitch circle, corresponding with the middle of the arcs of approach and of recess respectively. The construction is shown for tooth faces and flanks in Figs. 251, 252. In these figures, A and B are, as before, the centres of wheel and pinion, and C the pitch point, D C is the angle of obliquity of the link, and F C the perpendicular thereto. In Fig. 251 the centre of the wheel B is joined with the point F which lies on the side opposite to the link, and *a* is the centre of the arc for the tooth face of wheel B. In Fig. 252 the centre A of the wheel is joined with F on the side opposite to the link, and *a* is then the centre of the arc *b* forming the tooth face. The flanks of the wheel A are obtained by joining A, Fig. 251, with F which lies between A, and the link, C, D, and producing the line to *c*; *c* is then the centre for the flank *d*. For the tooth flank of wheel B, Fig. 252, join B to F between it and the link, C, D, and produce to *c*; *c* will then be the centre of the flank *d*.

The distances where *b* and *d* make contact are struck at a distance from the pitch point C equal to half the pitch, in order to have the points of absolutely correct action during approach and recess at equal distances from the pitch point. What the odontograph does, is to save all these separate constructions for every wheel by supplying the link at constant angle, and centres for a wide range of wheels.

In the odontograph, Fig. 253, the edge A B coincides with the line of centres A B in the previous figures, and the angle which it makes with the edge B D is the same as that already given, or 75°. Tables of radii are given on the sheet, and these correspond with the numbers marked down the edge C D.

The diagram, Fig. 254, represents the method of applying the instrument, being for tooth faces, and for tooth flanks. The pitch circles

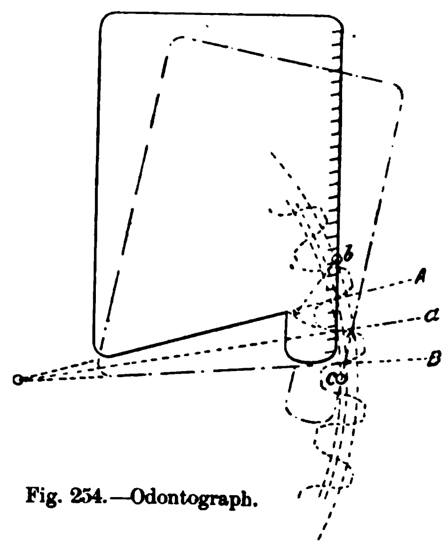


Fig. 254.—Odontograph.

are drawn, and pitched out. The point and root circles are set off, and struck. Lines are drawn through two pitches to the centre of the wheel, and the pitch bisected. The point of bisection represents the edge of the tooth. The slant edge of the scale is now laid against one of the radial pitch lines A, so that the divided edge just intersects the pitch line. A compass is set to the radius for the wheel in question, or the nearest radius thereto, on the "Scale of centres for the flanks of the teeth." One leg of the compass is set at that number on the edge of the scale, reckoning from B to C, and the other leg at the point of bisection, and the flank struck.

The slant edge of the scale is next moved to

the second radial pitch line B, the dotted outlines in Fig. 254, the divided edge again intersecting the pitch line. The compass is set to the radius for the wheel in question, or the nearest radius thereto on the "Scale of centres for the faces of the teeth." One leg of the compass is set at that number on the edge of the scale reckoning from B to D, and the other leg at the point of bisection of the pitch, and the face curve struck.

In internal gears the curves for the faces become flanks, and those for flanks are faces. In a rack the pitch lines are set out parallel, and the slant edge of the scale is laid against these.

Ohm.—The unit of electrical resistance. The reciprocal of conductivity of a conducting substance. The natural resistance is termed the *specific resistance*, or *ohmic resistance* of a substance, and varies according to its length and section. The ohm expresses that resistance which would allow an electro-motive force of 1 volt to pass a current of 1 ampère. About 10 ft. of a copper wire of No. 33 standard gauge, which has a diameter of $\frac{1}{100}$ in., has 1 ohm of resistance. Also a length of 60 in. of copper wire having a cross section of 1 millimetre has a resistance of 1 ohm. It is termed the B.A. Unit, or the British Association Unit. Conductors or circuits of very high resistance have their resistance expressed for convenience in millions of ohms, *i.e.*, "Megohms." This term is applied to the di-electric resistance of insulators, and is usually termed **Insulation Resistance,** because a resistance of such great measurement amounts practically to a non-conductor or insulator. Resistance is usually expressed as R. The ohmic value is written as $R = \omega$.

Ohmmeter.—A form of resistance indicator used in conjunction with a small hand magneto machine. The Evershed ohmmeter comprises two coils, lying at right angles to each other, acting upon one needle. One coil of fine wire is placed as a shunt to the terminals of the meter, to which is connected the magneto. The needle is deflected by the current in this coil to the end of a scale marked infinity. The second coil has one end connected to a terminal connecting to the magneto, and the other to a third terminal, to which the cable to be tested is attached. Any leakage to earth through the insulation must therefore pass through the second coil. The action of the magnetic effect of this coil upon the needle is to move it in the reverse direction to the first coil, the needle thus assuming an intermediate position according to the amount of leakage, this being dependent on the insulation resistance. The scale is graduated to read in ohms or megohms, either being available according to the position of a switch, the readings in one case being from 100,000 to 500,000 ohms, and in the other from 0·1 to 5 megohms. In the latest designs, a very compact portable testing set is produced by placing the ohmmeter and the magneto machine in one box, instead of separating them as hitherto.

Ohm's Law.—Expresses the relation between E.M.F. (written E), current (written C), and ohmic resistance (written R). Given any two of the three values, the other can always be known by Ohm's Law. The easiest way to remember the law is to write $\frac{E}{CR}$. Then by placing the finger over the value *required* to be known, the remainder gives the equation to produce it. Thus, supposing E is required, then—

$$\frac{\cancel{E}}{CR} = C \times R = E;$$

or, R required—

$$\frac{E}{C\cancel{R}} = \frac{E}{C} = R;$$

or, C required—

$$\frac{E}{\cancel{C}R} = \frac{E}{R} = C.$$

Oil Bath.—*See* **Lubrication, Tempering.**

Oil Can.—A convenient means of feeding oil to bearings and parts in such quantities as are required, from a few drops to sufficient to fill an oil box. A spring closed valve, which opens on the pressure of the thumb, regulates the supply. Spouts are made of lengths suited to the class of machinery, some of the oilers, such as for locomotives, being exceptionally long and slender.

Oil Engines.—The oil engine is a particular form of the gas engine, and belongs to the

variety of internal combustion engines among prime movers of the heat-engine class. The heat is generated by the combustion of liquid fuel. This is injected into the cylinder and burned ostensibly in the form of spray, but actually the liquid is more or less fully vaporised before combustion, and vaporisation is facilitated by the methods by which the oil is injected. The object is to disperse it over as wide an area as possible, that is to say, in a state of subdivision as fine as possible, the more completely and thoroughly to expose it to the effects of the heat by which it is vaporised, or to the oxygen which enables it to burn and generate the heat at each particle of liquid sufficient to vaporise the remaining more central parts of the particles which may be vaporised at the surface only by first contact with the cylinder heat. The facility with which a fuel is vaporised must of course very greatly depend upon the nature and quality of the fuel.

All the early oil engines worked with the commoner qualities of the lamp oil series of the mineral oils. Such oils had a moderately low flash point, and therefore were not difficult to vaporise or to ignite. The principle of action of these internal combustion engines may be best described by means of an actual example. Let us, for example, take the case of the Hornsby-Akroyd engine. In this engine there is attached to the rear cover of the cylinder an external vessel connected to the cylinder by a narrow bottle-neck passage. This external vessel is the vaporiser, and it may be a plain vessel internally, or may be fitted with internal ribs if required. This vaporiser must first be heated by an external source of heat to a sufficient temperature to volatilise the fuel. It is afterwards maintained sufficiently hot by the combustion of successive charges of fuel within it.

Assuming the vessel has acquired the necessary temperature, and the piston of the engine is at its outward position, a charge of oil is injected by a small force pump into the vaporiser, falling upon the hot surface of this and being thereby converted into vapour or more or less thoroughly gasified. The vaporiser is thus full of combustible vapour, which, however, cannot burn, there being no oxygen present to enable it to do so. The engine piston then commences to return, compressing the air in the cylinder, which had been drawn in on the outward stroke. This air is forced back into the vaporiser through the narrow bottle neck and enters with considerable velocity into the midst of the oil vapour, impinging upon the end of the vaporiser and spreading round the surface and generally mixing with the vapour. As the compression proceeds, the temperature of the mixed charge increases, and the general design and proportion are such that the mixture and temperature are correct for ignition at the moment that the piston reaches the extreme backward position. Explosion then occurs and the expanded air forces outwards the piston, re-entering the cylinder by way of the bottle neck, and also adding the necessary further amount of heat to the vaporiser which will enable it to vaporise the next charge of fuel. This is the complete cycle. But it has always been an object with designers to find some means satisfactorily to employ liquids in a state less refined than the cheaper lamp oils. Ordinary crude petroleum can be purchased for approximately one-third the price of the cheap lamp oils according to locality and circumstances, yet their calorific value is practically the same, and it is therefore of prime importance to be able to utilise such oils.

One of the most successful of the engines using heavy or crude oils, but also fully adapted for the use of light oils, is the Diesel engine. In this engine an entirely different method is employed both to vaporise the fuel and to ignite the charge at the proper time. To begin with, the fuel is not injected into a hot vessel, nor is it injected at all until such time as it is required to ignite. There is no heated vaporiser, that is to say, no separate heated metal. Instead, the charge admitted to the cylinder is pure air alone, and the rate of compression is so high that if there were a combustible mixture present in the cylinder this would be ignited by the temperature brought about by the high compression, which may attain about 510 lb. per sq. in. or say 35 atmospheres. But the fuel is only injected into this highly compressed and heated air when compression is at its maximum, that is to say, when the piston has completed its full return or compressive stroke. Fuel is then injected by means of a jet of air

compressed to about 800 lb. pressure per sq. in. This highly energetic air jet forcibly splits up the oil which is forced in with it by means of a small force pump, and spreads it throughout the charge of air in the cylinder. As soon as the oil spray enters the cylinder it takes fire with the air, the temperature of which is at or near 1,000° Fahr. Since the period of oil injection may be extended over some time, it follows that there is no explosion of the charge of fuel as with a gas engine, in which the whole of the charge may ignite at once, being present all at once in the cylinder, but that there is an extended period of combustion during which the initial pressure within the cylinder is maintained at the same point as the initial compression, or about 500 lb. Thus since compression is gradual up to the maximum, and the crank turns the dead point with this steady pressure upon it, and there is no serious rise of pressure when ignition takes place, but only a sustentation of the pressure already existing, there can be no shock, and this type of oil engine works with perfect quiet, though it must of course be constructed in a very heavy manner, as of course is proper and consistent with the pressures to be dealt with by its mechanism.

In the Priestman engine the oil is broken into spray and mixed with air before it is drawn into the cylinder. In the Hornsby-Akroyd engine the oil is injected into a heated vaporiser into which air is compressed, and one or other of these systems is followed in all oil motors. Except the Diesel, oil engines work on the Otto, or rather, to give credit where it is due, on the Beau de Rochas cycle, that is to say, with one explosive or working stroke in two revolutions. The ignition is brought about either by electricity, by the use of a tube heated by an external flame, or in the Akroyd type the vaporiser, being red hot, acts with the temperature of compression to produce ignition, while in the Diesel type ignition is due simply to the high temperature of the compressed air into which the fuel is sprayed.

There is a tendency for carbon to be deposited in the cylinder. This may be due to overheating of the oil by a too hot vaporiser, which will crack the oil instead of merely vaporising it. For petroleum, with which many engines work best, the specific gravity should be about 0·8, and the flash point 100° Fahr., but heavier oils of 0·82 and 150° Fahr. flash point may be employed, though they are apt to deposit more carbon than the lighter oils. According to the late Bryan Donkin the charge of oil and air as it enters a cylinder should be from 170° to 300° Fahr., and about 191 cubic in. of air should be supplied for each 0·015 cubic in. of oil vapour for a 1 HP. engine. Though as little as ¾ lb. of oil may be used per B.H.P. per hour, it is perhaps more usual to figure upon 1 lb., for while charges are small the small amount of oil which may be lost by condensation on the walls of the cylinder may represent quite a large percentage of the total oil consumed, and every endeavour should be made to diminish the risk of such condensation. The external vaporiser has certain obvious advantages on this score. The external vaporiser also favours the use of heavier oils than can be dealt with by other methods.

Owing to the comparatively high price of ordinary lamp oils, the use of crude oil has made of the Diesel engine a great success, and other engine makers have been stimulated to experiment with crude oil, and both Messrs Crossley Bros. and Messrs Hornsby have constructed and sold numerous engines using crude oil as their fuel. It is found that the injection with the oil into the vaporiser of a small quantity of steam enables the oil to vaporise more readily, and prevents the cracking action and deposit of carbon. In other respects their crude oil engines are similar to those already described. Not much has yet been done with oil engines except for land purposes. True, they have been used in launches and pleasure boats, but usually the small launch is driven by that type of oil engine which employs petrol as fuel. In the petrol engine, as employed on such launches and on motor vehicles, the fuel is gasolene or petrol or naphtha, and so readily volatile that it is at once taken up by a current of air flowing over it. Such engines are really gas engines, the gas being simply air loaded to a proper degree with hydrocarbon vapour. The mixture of the fuel vapour with the air is very complete, and combustion is correspondingly

perfect and rapid, amounting strictly to explosive violence.

In boat work the engine does not stop with the boat, but is simply disconnected. Neither are the engines made reversible, but the propeller shaft is driven through suitable gearing and clutches, or the blades of the propeller are made to swivel on the boss, so that with uni-directional rotation the propeller will drive the boat backwards and forwards according to the forward or reverse angle at which the blades of the propeller may be set. The Capitaine is one

Fig. 255.—Oil Engine.

of the best known oil engines for launch work, and many hundreds have been built by Messrs Tolch of Fulham for use on the Thames, Rhine, Niger, Nile, Congo, and other rivers.

Excepting the Diesel engine, oil engines have not yet been employed for power station work on a serious scale, though many have been used for private electric light work in country houses, and for pumping work. At the Yardley Power Station at Birmingham four Diesel engines drive the electric tramways. Tests by W. H. Booth on Diesel engines at Ghent and other places show an oil consumption of about 0·30 to 0·33 lb. per I.H.P. hour, and of 0·4 lb. per B.H.P. hour, with a heat efficiency of about 31 per cent. on the B.H.P., and of about 43 per cent. on the I.H.P.

Ordinary petroleum engines show heat efficiencies of 16 to 20 per cent., and a consumption per B.H.P. hour of 0·6 to 0·8 lb., with a mechanical efficiency of 75 to 85 per cent. As with the gas engine, efficiency is largely a matter of initial compression, and the rate of initial compression is of course limited by the risk of premature explosion, and cannot exceed a certain limiting degree unless, as in the Diesel engine, the fuel is not admitted to the cylinder until the time has arrived for ignition to take place. In this type, therefore, the only limit to the degree of compression is the will of the designer modified by the practical considerations of pressure and strength, leakage, and the exigencies of workmanship. Clearly if there be any opening for leakage this will become greater as the pressure becomes greater, but otherwise there appears no other limit. The temperature to which the charge of pure air will rise under heavy compression is, of course, very great, and much of this heat will pass uselessly to the water jacket, and must be taken into account when considering any proposition for higher pressures. As with the gas engine, a great proportion of the heat generated in the cylinder of an oil engine must pass into the jacket water. Hence the advantage of burning part of the charge after the working stroke has commenced so that the heat may be as directly as possible turned into work. Theoretically it is, of course, correct to produce all the heat potential of the fuel at the very start of the working stroke, but this statement must be modified when the cooling effect of the water jacket is taken into consideration, for the water jacket is a practical necessity that is demanded by the working conditions of the materials of the cylinder and piston. The De la Vergne Company, of New York, use common crude oil in the Hornsby-Akroyd oil engine which they make, and it is stated to work quite satisfactorily without any water injection.

Fig. 255 illustrates a Blackstone oil engine of 8 B.H.P. It is on the "Otto" cycle, thus; on the suction or forward stroke of the piston, a charge of oil or air is drawn through the vaporiser into the cylinder. It there becomes mixed with a sufficient quantity of pure air to form an explosive mixture. Then the backward stroke of the piston compresses the charge into the combustion chamber. As the crank passes the in-centre, the ignition valve opens to allow the charge to pass into the ignition chamber, in which it explodes and imparts the working stroke. On the second backward stroke of the piston the products of combustion are expelled through the exhaust valve. In order to start, the vaporiser and the igniter are heated for from four to six minutes by a lamp. The flywheel is then turned forward by hand, or a self starter can be used, to obtain the first explosion, after which when the engine begins to work the heat for vaporisation and ignition is maintained by the successive explosions. A timing valve regulates the period of ignition. A shaft governor controls the vapour valve and so regulates the oil consumption to the power given off. Any ordinary oil may be used, but the efficiency depends on the quality of the oil. The engine consumes about $\frac{3}{4}$ pint per B.H.P. per hour, larger engines $\frac{5}{8}$ of a pint. A water jacket encircles the cylinder, and a constant supply of circulating water prevents the temperature from rising above 120° Fahr.

Oil Filter.—Used for extracting foreign matter from oil, in order that it may be used over again. The dirt and impurities are separated by passing the oil down through cotton waste, and sometimes in addition through water heated by a steam coil, the effect being to cause the oil to discharge its impurities as it rises up through the water.

Oil Grooves.—Shallow half-round grooves cut in bearing surfaces to allow lubricating oil to distribute itself. They are made in brasses and bushes, in journals, and on flat faces, and should radiate from the oil hole in such a manner as to cover the area to be supplied. Oil grooves are cut with a round-nose chisel and smoothed out with a bent rat-tail file; in some cases they can be machine cut, and there are special machines for cutting the spiral grooves in brasses, by a tool held in a bar to which a combination of a longitudinal and a twisting movement is imparted.

Oil Hardening.—This is a milder, less pronounced method of hardening than that done in water. The degree of hardening obtained is less, the elastic limit is raised, and there is less risk of cracking of the steel.

Oils.—Oils may be classed as hydrocarbon oils and fatty oils. The first are a mineral product, derived from wells in several countries, the second are extracted from the seeds and fruit of plants, or from portions of animals. The distinction is also made between fixed or fatty oils, and essential or volatile oils. Oils are colourless, or of a slight yellow tint, and will not mix with water. The vegetable oils are extracted by pressure, with or without the aid of heat. Animal oils are separated by melting. Some of the fatty oils, especially, absorb oxygen when exposed to the air in thin coatings, and therefore become hardened. These drying oils are useful in painting. Other oils do not dry, but remain practically unchanged, and these are used in lubricating. The comparative fluidity or solidity of the oils depends on the relative proportions of olein, stearin, and palmitin which they contain. The fluid oils have more olein, while the hard fats contain a larger proportion of stearin and palmitin.

For questions of flash point, viscosity, adulteration and other practical matters, *see* **Lubricants.**

Oil-Testing Machines.—Machines having revolving belt-driven spindles for ascertaining the coefficient of friction of various oils, tested under similar conditions of speed and pressure. There are many designs, and many tables have been published giving the results of tests.

But oil-testing machines do not show the conditions of actual service, in which bearings are often rough, duty intermittent, and oil supplied irregularly. They do not show the tendency of an animal oil to gum by exposure to air and dust. They only indicate viscosity, which can be ascertained suitably by observing the duration of flow from a pipette. The tendency to gum on long exposure is as important a feature as viscosity. Again, viscous oils, as heavy petroleum cylinder oils and greases, show greater frictional resistances than lard. But if lard is substituted on heavy running machinery more of it will be required, and it will have to be applied more frequently. The mere reduction of friction is of less importance than the durability of the more viscous lubricants. In the experiment of rubbing plug and ring gauges together with thin and thick oils, it is found that the period which elapses before seizing occurs increases with viscosity. In other words the thicker oils take longer to escape from between the surfaces.

Professor Denton has shown that the durability of lubricants depends on the rate at which they will feed the bearings, and escape therefrom. Hence, that the greater the viscosity of an oil, without being incapable of feeding to a journal at a uniform rate, the greater will be its durability. And further, that uniformity in the rate of feeding oil or any lubricant exerts the most important influence of any element which enters into the determination of its character as a satisfactory lubricant. But the oil-testing machines eliminate all irregularities such as exist in practice, both in regard to methods of feeding, and roughnesses of bearings and journals. Consequently deductions made at the testing machines are often contrary to those founded on practice and experience.

Old Sand.—The black sand lying on the foundry floor, and which has been used for box filling year after year. Portions are used for facing sands with admixtures of new sands.

Oliver.—An old form of hammer nearly displaced by the various power hammers. It comprises a longitudinal beam or shaft of timber, pivoted in bearings in uprights. A hammer shaft is tenoned into the beam and also a long lever. A cord passes from the

latter to a treadle below and to a spring pole overhead, which in the normal state holds the hammer off its work. It is pulled down on the work by the treadle, the work being laid on an anvil, and is released by the pole. It is often termed a bolt oliver, from one of its functions, also a holliper. The term oliver is also applied to a pair of swages united with a spring handle.

Open Belt.—A belt that is not crossed. *See* **Belting.**

Open Divided Scale.—A scale in which only the end primary divisions are subdivided.

Open-Hearth Furnaces.—*See* **Open-Hearth Steel.**

Open-Hearth Process.—The process of making steel in open-hearth reverberatory furnaces. It includes several variations in methods, both basic and acid, just as in Bessemer metal. The differences are chiefly in the character of the linings of the furnaces.

Acid Process.—In this, the bed is made of silica bricks covered with a sand bottom. As the bed is concave in section, the deeper portions towards the sides are roughly made up with silica bricks in stepped fashion. The sand bottom is made in layers, each of which is glazed on in thicknesses of about $\frac{1}{2}$ in. The charge for a furnace comprises about 75 to 80 per cent. of pig, and 25 to 20 per cent. of scrap—crop ends usually—from bars or rails. The pig may be charged first, or both together. The valves are reversed about every twenty to thirty minutes, and in about three to three and a half hours the charge will be melted. Pure hæmatite ore is now introduced in small quantities, and the boiling stage ensues. If large quantities are thrown in, the charge will overflow. The reactions which result are due to the oxide of iron acting on the carbon, and so eliminating it from the iron, according to the reaction :—

$$C + Fe_2O_3 = CO + 2FeO$$
$$2C + 2FeO = 2CO + 2Fe.$$

The carbon is thus removed to a mere trace. The melter makes a rough test at intervals by taking a button of the metal, hammering it flat, and fracturing it. If the carbon remains in excess while the boiling is ended, more ore is added. If it is too low, more pig is thrown in, and herein lies the advantage of the open-hearth process over the Bessemer.

Tapping is done at the stage of decarbonisation required, and ferro-manganese is added either in the furnace, or as the metal is being teemed into the ladle. The alloy contains about 6 per cent. of carbon, and this recarbonises the iron to the degree required, and the degree of the same is easily regulated. A sample is taken and tested for cold bending, and for subsequent analysis. Ladles are illustrated under **Casting Ladles.** As in the Bessemer, so in the acid Siemens process, all the phosphorus and sulphur present in the pig remain in the steel, so that an iron low in these elements must be used. It should not contain more than 0·03 per cent. of either element.

Basic Process.—In this, as in the Bessemer, the furnace has to be lined with a basic material, and lime is added to the charge. It came after the acid, and the Batho furnace was a form designed specially for basic work. But at present the same design of furnace is generally used for both methods, subject to minor modifications in the lining. Actually though a basic lining is used, acid silica bricks are employed for the roof and walls, because they are strong enough to support their weight, which basic bricks are not. Silica bricks away from the metal do not cause fluxing action if they are not subjected to pressure. The most suitable basic material is the burnt dolomite mixed with tar. This is often glazed over a bottom of silica bricks. Magnesia bricks (burnt magnesite) are suitable, but more costly; and burnt magnesite is used as a lining. The dolomite and tar are glazed on in successive layers until the full thickness is attained. Other materials have been tried with less success, as chrome iron ore, bauxite, and lime.

In charging the furnace, a small quantity of lime and ore is strewn over the bottom before the pig is introduced. Small charges of lime and ore are included with this, followed by the greater portion of the scrap, and the melting proceeds. Iron ore, or ferric or ferrous oxides of iron are added, with lime, to decarbonise the bath. Buttons of metal are tested from

Fig. 256.—50-Ton Open-Hearth Steel Furnace. (Barrow Hæmatite Steel Co., Ltd.)

time to time, and tapping is done when the required stage of decarbonisation is reached. The ferro-manganese is always added in the ladle.

Open-Hearth Steel.—Mild or low carbon steel made in reverberatory furnaces of the Siemens type, using regenerators. It includes the original Siemens method of pig and ore, and the later Siemens-Martin of pig and scrap, and the present usual practice of pig, ore, and scrap. "Open-hearth" relates to the open bath of metal lying on the bed of the furnace, as distinguished from the closed crucibles, and converters of other steel-making processes.

The open-hearth processes, though a year or two later in time than the Bessemer, have grown much more rapidly than the latter. The reason is that the results are under better control, because the metal may remain in the bath for a while, until the exact grade is obtained, which cannot be done in the Bessemer converter. The original object of Siemens was the *fusion* of steel on the hearth, instead of in crucibles. Not until 1867 was the first patent for steel *manufacture* taken out. The method by which a temperature sufficiently intense to fuse the steel is obtained, is that which was invented by Siemens, and first applied to a regenerative steam engine, which was not successful. It consists of brick-work chambers of chequering, termed *regenerators*, within which heat from previous combustion is stored and made to heat gas and air on its way to the furnace hearth. The heat produced was so intense that great damage resulted to the early furnaces. The first successes were due in a great measure to the French firm of Messrs Pierre & Emile Martin, of Sereuil, who worked under a license from Messrs Siemens.

There are many variations in the details of working open-hearth furnaces, but the following are the essential elements, Fig. 256. The furnace O, built of silica bricks, is enclosed in stout plates of cast iron or steel, bonded together and carried on steel girders. The hearth is lined with refractory material (silica); chambers are built at each end with brick-work chequering, two at each end, one, P, being for gas the other, Q, for air. The regenerators for air and gas, though adjacent, are separated by walls so that no mixture can take place. After the first heating of a furnace, the air and gas are introduced at regular intervals, reversing usually at about every twenty minutes when the furnace is in full work. The gas valve is reversed first, and the air valve a few seconds later. Two to three ports are required for gas and for air, but the latter, R, R, are placed at a higher level than the former, S, S, being generally at the top of the furnace. Combustion takes place on the hearth of the furnace, and the products of combustion pass away indifferently through the gas, and air ports at the opposite side, where free communication exists for the time being to the chimney, heating up the regenerators at that end on their way. The passage of the gas and air is controlled by ordinary valves, one for each supply, and generally of mushroom type, and by reversing valves by which the direction of the entry of the currents of gas and air are directed from one set of chequering to the set at the other end of the furnace. These valves are generally of the butterfly type illustrated under **Gas Reversing Valve**, though there are other types sometimes used. A strong chimney draught is essential, and it is found that a high chimney temperature is economical. The regenerators are sometimes made of the same dimensions, but it is better to make those for air larger than those for gas, the temperature for the air being a more economical factor than that of the gas.

An essential to the long life of the furnace is the provision of dust, and slag catchers. A large amount of dust from ore, or lime from the furnace is carried along with the gases, and this if not arrested will choke the regenerators and flux the bricks. To arrest these, many modern furnaces are provided with a chamber between the ports and the regenerators to catch the dust, and also to receive any slag that may boil over.